2

Land Use and Water Management

The Klamath River watershed covers 12,000 mi^2 of northern California and southwestern Oregon and extends more than 350 river mi from its headwaters to its estuary at the Pacific Ocean. The watershed derives its unique character largely from its geology and climate (Mount 1995), which are discussed in the first quarter of this chapter. The rest of the chapter describes land uses and resulting changes in the basin since 1848, the beginning of the gold-mining era. The topography, hydrology, ecosystems, and unusual plant and animal communities of the watershed reflect diverse dynamic processes in the landscape of today and in the past. These features of the watershed are tied to the natural resource economies of the watershed, which include logging, grazing, agriculture, mining, and fisheries. The diversity of land uses and landscape features poses a significant challenge to land managers and those seeking to restore the watershed's aquatic communities. As this chapter shows, simple or uniform approaches to restoration of impaired ecosystems are unlikely to succeed in a watershed as diverse as that of the Klamath River.

DESCRIPTION OF THE KLAMATH RIVER WATERSHED

Geologic Setting

The physiography of the Klamath watershed records the oblique convergence between the North American tectonic plate and the plates that underlie the Pacific Ocean. The Juan de Fuca and Gorda Plates, which lie off the shore of Washington, Oregon, and northern California, are being subducted in a northeasterly direction beneath western North America, forming the Cascadia subduction zone (Figure 2-1). A consequence of the subduction is the formation of an extensive north-south oriented chain of volcanoes known as the Cascadia volcanic arc or Cascade Range. The arc includes two of the more prominent volcanoes in the upper Klamath watershed: Mount Shasta and Mount Mazama (the site of Crater Lake). The volcanic arc bisects the Klamath watershed, dividing the upper basin from the lower basin (Figure 2-1). The upper basin, including the large natural lakes and their tributaries, lies in

Tectonic Setting of Klamath Watershed

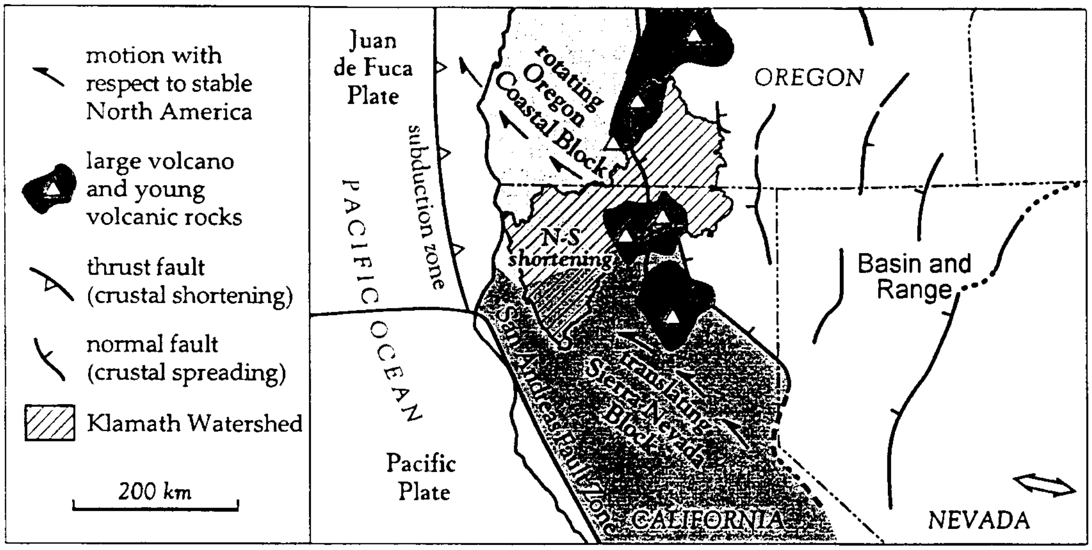

Figure 2-1. General tectonic setting for northern California and southern Oregon illustrating the Cascadia subduction zone, the Cascade volcanic arc, the Basin and Range Province, and the Oregon fore-arc and Sierra Nevada blocks. Note that the Klamath watershed occurs at the intersection of these tectonic blocks. Source: modified from Wells and Simpson 2001.

the back-arc of the Cascadia margin. The lower basin—which includes the mountainous, steeper portions of the mainstem Klamath and the Scott, Salmon, and Trinity rivers—lies in the dynamic fore-arc area of the margin. The Shasta River straddles the tectonic boundary between the back-arc and the fore-arc (Figure 2-1); its confluence with the mainstem Klamath occurs in the fore-arc region.

Geophysical and geodetic surveys coupled with geologic mapping efforts have shown that portions of the fore-arc and back-arc regions of the Cascadia margin form discrete crustal blocks, each with its own motion (Wells et al. 1998, McCaffrey et al. 2000). The motion of these blocks and their interactions with each other have dictated the dynamic topography of the region.

Within the Klamath watershed region, the back-arc portion of the Cascadia margin is part of the crustal block known as the Basin and Range Province. Although attached to North America, the province is undergoing east-west extension of as much as 1 cm/yr (Bennett et al. 1998, Magill et al. 1982). Right-lateral shear oriented north northwest-south southeast occurs along the western edge of the province and is superimposed on the east-west extension (Bennett et al. 1998, 1999). This shear has formed the distinctive grabens showing north-northwest south-southwest orientation, which appear topographically as fault-bound troughs and valleys of the Klamath Lake area. The crustal extension of the northwestern basin and range in southern Oregon and northern California has been accompanied by widespread Neogene volcanism that has formed the distinctive volcanic tablelands and broad valleys and marshes of the upper tributaries within the Klamath watershed.

Unlike most watersheds, the Klamath watershed has its greatest relief and topographic complexity in its lower half rather than in its headwaters. This unusual physiography stems from the location of the fore-arc region, which encompasses the lower half of the watershed. The Cascadia fore-arc of northern California is arguably the most dynamic landscape in the region (Mount 1995). The regional compression associated with subduction of the Gorda Plate immediately off shore has produced some of the fastest rates of uplift recorded in California. Additionally, the fore-arc occurs at the poorly defined intersection between two large crustal blocks (Figure 2-1): the Sierra Nevada block and the Oregon fore-arc block (Wells et al. 1998, McCaffrey et al. 2000). The Sierra Nevada block includes the Sierra Nevada-Great Valley of central California and the Klamath Mountains and Coast Ranges of Northern California. The block is bounded on the east by the Basin and Range Province and on the west by the San Andreas-Coast Range Fault system (Wells et al. 1998). Geodetic surveys indicate that the block is moving northwest relative to North America and is rotating in a counterclockwise manner (Argus and Gordon 1990). The Oregon fore-arc block extends from the Cascadia subduction zone on the west to the Basin and Range on the east. Its southern boundary occurs at the transition to the Sierra Nevada block, roughly in the vicinity of the California-Oregon border. The Oregon fore-arc block is rotating clockwise relative to North America (Wells et al. 1998).

The lower Klamath River watershed, which extends from Iron Gate Dam to the Klamath estuary, traverses the northern portions of the Sierra Nevada block along its transition to the Oregon fore-arc block (Figure 2-1). The steep, rugged watersheds of the lower Klamath, coupled with the bedrock-controlled main stem, reflect the rapid uplift in the region and the constant adjustment of the river to its dynamic landscape (Mount 1995). The patterns of uplift and faulting also control the orientation of most tributaries. Because the main tributaries of the lower Klamath River—the Shasta, Scott, Salmon, and Trinity rivers—are important for salmonids, their individual geologic features are of interest.

The Shasta River watershed is at the junction between the Basin and Range Province, in the Sierra Nevada block within the Cascadia volcanic arc. Its watershed, which originates at Mount Eddy, encompasses about 800 mi^2. Like the Scott River watershed to the west, the Shasta has a large central alluvial valley, steep headwaters on the west, and a steep gorge in the lowermost portion of the watershed. The eastern portions of the watershed are dominated by Tertiary and Quaternary volcanic flows and by debris flows associated with Cascade volcanism. The lower gorge and westernmost edge of the basin are underlain by Paleozoic metamorphic rocks of the Sierra Nevada block. The most conspicuous topographic feature of the Shasta Valley is a large Pleistocene volcanic debris avalanche derived from nearby Mount Shasta that creates the unusual hummocky topography in the upper reaches of the valley (Crandall 1989). The north-south orientation of the valley is associated with large basin and range faults similar to those controlling the formation of the upper basin. The hydrology of the Shasta River watershed, unlike that of the other tributary watersheds of the lower basin, is dominated by discharge from numerous springs.

The Shasta subbasin lies within the extensive rain shadow of the Salmon and Marble mountains. Precipitation averages 12-18 in/yr and is as low as 5 in/yr in the vicinity of Big Springs (Mack 1960). The bulk of this precipitation occurs from October to March as snow. Like the upper Klamath basin, the Shasta subbasin has warm summers (mean daily temperatures commonly exceeding 30°C) and cool winters (mean daily temperatures of 5°C). The average length of the growing season in the basin is about 180 days (Mack 1960). As discussed in Chapter 8, climate may change over the coming decades.

The Scott River watershed lies at the transition between the Cascadia volcanic arc and the fore-arc basin (Figure 2-1). The watershed, which is about 820 mi^2, has headwaters nearly 8000 ft above sea level in the Salmon Mountains along the west side of the watershed. The Scott joins the Klamath River at river mile 142. The physiography of the watershed shows elements of its neighboring watersheds. Like the Salmon watershed, the headwaters of the Scott are heavily forested and have annual precipitation of 50 in or more, high water yields, and extensive snowpack more than 4000 ft above sea level. Like the Shasta watershed, the Scott has a large, fault-bound alluvial valley in the middle portions of the watershed that supports extensive agriculture and grazing. This valley, like the eastern portion of the Scott watershed, lies in the rain shadow of the Salmon and Marble mountains; mean annual precipitation is about 20 in. The Scott River, like the Shasta River, has a steep bedrock gorge downstream of the alluvial valley and above its confluence with the Klamath River. Mean daily temperatures in the valley exceed 32°C during late July or early August (peaks, above 40°C); mean daily temperatures reach 10°C in winter (Rantz 1972, CDWR 2002).

The tributaries of the Scott River strongly affect the hydrology (Mack 1958) and aquatic habitat of the basin. The fourth-order tributaries of the west side of the watershed—including Scott, French, Sugar, Etna, Patterson, Kidder, and Shackleford creeks—are steep-gradient, perennial bedrock tributaries. Several of these tributaries have built coarse-grained alluvial fans where their gradients decrease as they meet the valley floor. In contrast, the East and South Forks of the Scott and the third- and fourth-order creeks of the Scott River Canyon, a tributary of the Scott, enter the river in steep reaches and have no alluvial fans. The relatively dry east side of the watershed has several low-gradient ephemeral tributaries; Moffett Creek is the largest and most important of these.

In its upper reaches and within the canyon, the Scott River is primarily a bedrock river characterized by alternating step-pool and cascade reaches with discontinuous riffle-pool reaches containing narrow alluvial floodplains. Within the Scott Valley, the river has various forms that are controlled principally by grain size, slope, tributary contributions, and channel modifications. In coarse-grained, steep-gradient reaches of the river, the channel appears to be actively braiding. In low-gradient, fine-grained reaches with cohesive banks, the channel alternates between a single-channel meandering river and a multichannel, anastomosing river, albeit with numerous modifications for flood management and irrigation diversions. Some incision within the channelized reach has lowered the channel bed by several feet (G. Black, Siskiyou Resource Conservation District, Etna, California, personal communication, 2002). Sloughs, which indicate historical channel avulsion and cutoff events, apparently were numerous before agricultural development of the valley. Several large sloughs remain in the valley along the west side and receive flow from tributaries and from the main stem during large flow events.

At 750 mi^2 the Salmon River is the smallest of the four major tributaries to the lower Klamath basin (Figure 2-1). The Salmon watershed is steep and heavily forested and, in comparison with its neighboring watersheds, relatively undisturbed. The bulk of the main stem and its tributaries consist of bedrock channels with numerous step-pool and cascade reaches and narrow riparian corridors. The watershed is located entirely within the Cascadia fore-arc region on the Sierra Nevada block. The high uplift rates and the lack of extensional tectonics have prevented the formation of any important alluvial valleys, such as those of the Scott and Shasta drainages. The rugged terrain and the lack of a large alluvial valley have limited some of the land-use activities that have affected anadromous fishes in other tributaries.

The Trinity River is the largest tributary to the Klamath River. At 2900 mi^2 with an annual average precipitation of 57 in, it is also the largest contributor of runoff and sediment to the Klamath River. It is a rugged, step, and heavily forested watershed. Its eastern portions in the Trinity Alps and Coast Ranges reach elevations in excess of 9000 ft and support thick winter snowpacks. The bulk of the watershed is below 5000 ft in elevation and is dominated by conifer and mixed conifer and hardwood forests. The confluence of the Trinity and Klamath rivers is located 43 mi upstream of the mouth and exerts considerable influence over conditions in the lowermost Klamath River and its estuary. The Trinity watershed is located entirely within the Sierra Nevada block, west of the Cascade volcanic arc. The basin lines close to the junction between the Cascade subduction zone and the northernmost San Andreas Fault. The physiography of the watershed is controlled by high rates of uplift and a series of large, seismically active northwest trending faults. The eastern half of the basin is composed of rocks of the Klamath Mountains Geologic Province, while the western half is dominated by rocks of the Coast Range Geologic Province. Both provinces contain rock types that are prone to landsliding and high rates of erosion, particularly when disturbed by poor land-use practices. The high rates of uplift, unstable rock types, and high rates of precipitation produce a naturally dynamic landscape and a river with a variable hydrograph and sediment yields.

Uplift in the Trinity watershed has precluded the formation of extensive alluvial valleys such as those found in the Scott and Shasta watersheds. The upper reaches of the main stem and the tributaries support steep-gradient rivers with numerous cascades. In portions of the main stem and the South Fork, however, low-gradient reaches with narrow alluvial valleys occur. These reaches historically supported dynamic, meandering coarse-grained channels that provided ideal spawning and rearing habitat for salmon and steelhead. The size of the Trinity watershed, coupled with its extensive high-quality spawning and rearing habitat, made the Trinity a productive source of coho salmon and other anadromous fishes (USFWS/HVT 1999).

Climate and Historical Hydropattern

The tectonic setting of the Klamath watershed exerts primary control over its irregular distribution of precipitation. The uplift of the Cascadia fore-arc and the formation of the Cascade volcanic arc have produced an important rain shadow in the upper basin and the Shasta Valley. The upper watershed has a relatively low mean annual precipitation (27 in; Risley and Laenen 1999), about half of which falls as snow. Precipitation in the lower watershed varies greatly and reaches as much as 100 in/yr in the temperate rain forest close to the coast. The rapid uplift of the fore-arc has produced a series of steep mountain ranges with strong orographic effects. Where mountain ranges exceed 5000 ft above sea level, they maintain large winter and spring snowpacks in wet years and are associated with very high amounts of runoff during warm winter storms.

Annual runoff, as measured near the mouth of the Klamath River, is approximately 13 × 10^6 acre-ft. The upper watershed above Iron Gate Dam, which comprises about 38% area of the total watershed area, provides only 12% of the annual runoff of the watershed. The low yields from the upper watershed are a product of its location in the rain shadow of the Cascades, its low relief, and its extensive marshes and lakes that increase hydraulic retention times. In contrast, the tributaries of the lower watershed dominate the total runoff of the Klamath watershed. Their high runoff stems from their high relief and the orographic influence of the Coast Ranges, Trinity Alps, and the Marble, Salmon, and Russian mountains. For example, one relatively small tributary, the Salmon River, supplies runoff about equal to that of the entire upper watershed, but from less than one-fifth of the area (Table 2-1).

The hydropattern, or timing of runoff, varies throughout the watershed. Seasonal runoff from the upper watershed is regulated by the long and complex transport pathways in the basin and, historically, by the natural buffering effect of overflow into the Lost River and Lower Klamath and Tule lakes.

Under unregulated conditions, peak runoff from the upper watershed would typically occur in April and decrease gradually to minimums in late August or early September. Flow regulation and land-use activities in the upper basin have altered the hydropattern. Unlike the upper basin, the lower Klamath basin exhibits two potential flow peaks, depending on the water year. Subtropical storms strike the Klamath watershed with high frequency from late December to early March and are responsible for all peak daily discharges in the Klamath main stem and its tributaries. The short hydraulic retention times of the tributaries to the lower Klamath basin enhance the effect of these storms. The second and more predictable flow peaks are associated with spring snowmelt. The timing of the snowmelt pulse varies, but it usually occurs in April. Historically, the decline in flow from the tributaries to the lower basin was gradual and reached minimums in September. During the low-flow periods in the late summer or early fall when no precipitation occurs, spring-fed tributaries such as the Shasta River and flow from the upper basin constitute the bulk of base flow in the main stem of the lower basin.

Even the Trinity, the largest annual contributor of runoff to the Klamath, historically provided very little flow in the late summer and early fall.

AQUATIC ENVIRONMENTS IN THE UPPER KLAMATH BASIN

The upper Klamath basin encompasses about 5700 mi^2 (USBR 2000a). Major lakes in the upper Klamath basin include Upper Klamath Lake (now 67,000 acres at maximum lake elevation), Lower Klamath Lake (historical maximum area, 94,000 acres; now about 4700 acres), Tule Lake (historical maximum area, 110,000 acres; now 9450-13,000 acres), Clear Lake, and Gerber Reservoir (see Chapter 3).

Upper Klamath Lake, now the largest water body in the Klamath basin, receives most of its water from the Williamson and Wood rivers. The Williamson River watershed consists of two subbasins drained by the Williamson and Sprague rivers. The Williamson River arises in the Winema National Forest, flows to the north through Klamath Marsh, and turns south to Upper Klamath Lake. The Sprague River arises in the Fremont National Forest and flows westward to connect with the Williamson River just below the Chiloquin Dam (Figure 1-1). The Sycan River, a major tributary of the Sprague, drains much of the northeastern portion of the watershed. Both the Williamson and Sprague subbasins are primarily forested (about 70%). Other important land-cover types are shrub and grassland (14%), agriculture (6%), and wetland

Table 2-1. Runoff, Yield, and Basin Areas for the Klamath Watershed[a]

Location	Average Annual Runoff, 1000 acre-ft	Drainage Area, mi^2	Runoff, %	Drainage Area, %	Ratio of Average Runoff to Drainage Area, acre-ft/mi^2
Klamath River below Iron Gate Dam	1581	4630	12	38	341
Shasta River near mouth	136	793	1	7	172
Scott River at mouth	615	808	5	7	761
Other tributaries	615	709	5	5	867
Klamath River below Scott River	3020	6940	23	57	435
Indian Creek at mouth	360	135	3	1	2667
Salmon River at mouth	1330	750	10	6	1773
Other tributaries	1350	650	10	5	1500
Klamath River at Orleans	6060	8475	47	70	715
Trinity River at Hoopa	3787	2950	29	24	1283
Other tributaries	3021	675	23	6	4476
Klamath River at mouth	12868	12100	100	100	1109

[a]Data compiled from reports of the California Division of Water Resources 2002, representing average current conditions (including depletion caused by consumptive use) and gage records of the U.S. Geological Survey. Periods of record for data vary by site from 22 to 50 yr, principally between 1951 and the present, and include both pre- and post-Trinity River Diversion operations.

(6%; Boyd et al. 2002). The Williamson and Sprague together provide over half the water reaching Upper Klamath Lake (Kann and Walker 2001).

The Wood River is the second largest source of water (16%) for Upper Klamath Lake (Kann and Walker 2001). Annie and Sun creeks join to form the Wood River. The watershed drains an area northeast of Upper Klamath Lake and extends from the southern base of the mountains that surround Crater Lake to the confluence of the Wood River with Upper Klamath Lake by way of the northern arm (Figure 1-3), which is often called Agency Lake. Although primarily forested, the Wood River has extensive agricultural lands and wetlands. The balance of the water reaching Upper Klamath Lake is derived from direct precipitation on the lake and flows from springs, small streams, irrigation canals, and agricultural pumps.

Before development of the Klamath Project, Lower Klamath Lake (Figure 1-3) was often larger than Upper Klamath Lake. Flows from the Klamath River, supplemented by springs around the lake, supported a complex of wetlands and open water covering approximately 80,000-94,000 acres in the spring, during high water, and 30,000-40,000 acres in late summer. The open water provided habitat for suckers, and the variable combination of open water and marsh created important habitat for migratory birds along the Pacific Flyway, making it one of the most important aquatic complexes for waterfowl in the West. By 1924, however, development of the Klamath Project eliminated more than 90% of its open water and marsh. Only about 4700 acres of open water and wetland remain. Draining the lake led to the extirpation of sucker populations that had been in the lake (USBR 2002a), and also eliminated much of the habitat suitable for waterfowl and other birds.

Connections between the Klamath River and Lower Klamath Lake were severed by development, which changed the hydrology of both the lake and the river in ways that are not entirely clear. Before 1917, when railroad construction blocked the Klamath Straits, "water flowed from Upper Klamath Lake, through the Link River into Lake Ewauna, and then into the Klamath River. Between Lake Ewauna and Keno, the river meandered through a flat, marshy country" (Henshaw and Dean 1915, p. 655) for about 20 mi before descending over a natural rock barrier that stretched across the river at Keno. "Water in the river periodically backed up behind the reef at Keno and spread out upstream, flowing into Lower Klamath Lake through Klamath Straits" (Weddell 2000, p. 1). Today, connectivity between Lower Klamath Lake and the rest of the basin is limited to water pumped through Sheepy Ridge from Tule Lake and water from irrigation channels that lead to the Keno impoundment (USFWS 2001, Figure 1-2).

Before the Klamath Project, the lake and wetlands probably retained substantial amounts of early spring precipitation and some of the high flow of the river. "By storing and subsequently releasing this water into the river, Lower Klamath Lake would have augmented the effects of groundwater in shifting the Klamath River hydrograph to the river" (Weddell 2000, p. 7). Lower Klamath Lake was "neither an undrained basin nor a thoroughly drained floodplain. At times, its waters flowed into the Pacific Ocean via the Klamath River, yet this drainage was only partial" (Weddell 2000, p. 8).

Before 1924, suckers appear to have been abundant in Lower Klamath Lake, even after its connection to the river was severed in 1917. Suckers migrated into the lake from Sheepy Creek, a spring-fed tributary on the western edge of the lake, in numbers large enough to support a fishery (Coots 1965, cited in USFWS 2001).

Before the Klamath Project, Tule Lake (Figure 1-3) varied from 55,000 to over 100,000 acres, averaging about 95,000 acres (making it often larger than Upper Klamath Lake). Like Lower Klamath Lake, Tule Lake was connected seasonally to the Klamath River. During periods of high runoff, water from the Klamath River flowed into the Lost River slough and down the Lost River to Tule Lake. The direction of the river's flow is now determined by operators of the Klamath Project, depending on irrigation needs. Most of the former bed of Tule Lake has been drained for agriculture, leaving about 9450-13,000 acres of shallow lake and marsh.

The fluctuation in surface area of Tule Lake afforded by its connections to the Klamath River may have been critical in maintaining the high aquatic productivity of Tule Lake and its wetlands (ILM 2000). Tule marshes on the north and west sides of the lake supported populations of colonial nesting water birds and summer resident waterfowl. The large fish populations in the lake supported what was probably the largest concentration of nesting osprey in North America (ILM 2000). Much of the historical variability in lake and marsh habitats has been lost as a result of management. Nevertheless, well into the 1960s and early 1970s, Tule Lake National Wildlife Refuge was considered the most important waterfowl refuge in North America; duck populations exceeded 2.5 million at their peaks. Siltation caused by agriculture and loss of wetland productivity has occurred in the last several decades, however, and waterfowl populations have declined (ILM 2000).

Historically, suckers in Tule Lake and the Lost River were abundant enough to support cannery operations along the Lost River (USFWS 2001). After the Klamath Project drained most of Tule Lake for agriculture and diversion dams of the project blocked the access of suckers to spawning areas in the Lost River, sucker populations declined substantially (Scoppettone et al. 1995, USBR 2002a).

The hydrology of Tule Lake and of the Klamath River first changed in 1890, when settlers built a dike across the Lost River slough in an attempt to protect lands near Tule Lake from flooding (USFWS 2001). The dike prevented Klamath River floodwaters from overflowing into the Lost River drainage and ultimately draining into Tule Lake. As is the case with respect to Lower Klamath Lake, the amount of water that flowed from the Klamath River into Tule Lake and the effect of this overflow on the historical hydrograph of the Klamath River are unclear. Estimates of historical Klamath River flows are derived from measurements recorded before Lower Klamath Lake was disconnected from the Klamath River, but the measurements were taken after Tule Lake was disconnected from the river.

The Lost River drains Clear Lake and flows north toward the Klamath River (Figure 1-3). The structure and hydrology of the Lost River have been highly modified by the Klamath Project. Historically, the Lost River was connected to the Klamath River during periods of high flow via the Lost River slough. There is now no direct outlet to the Klamath River, although diversion canals can be used to send water into the Klamath Project (Figure 1-2).

Aquatic habitats have been modified throughout the upper Klamath basin, but the Lost River watershed has been particularly altered by development of the Klamath Project. The Lost River, once a major spawning site for suckers, today supports few suckers (Chapter 6). According to the U.S. Fish and Wildlife Service (USFWS), the Lost River "can perhaps be best characterized as an irrigation water conveyance, rather than a river. Flows are completely regulated, it has been channelized in one 6-mi reach, its riparian habitats and adjacent wetlands are highly modified, and it receives significant discharges from agricultural drains and sewage effluent. The active floodplain is no longer functioning except in very high water conditions" (USFWS 2001, III-2-24). New lakes have been created and old lakes drained, new waterways have been dug and old rivers turned into irrigation ditches, and new sucker habitat has been created while original sucker habitat has been eradicated.

Before 1910, a natural lake, marsh, and meadow complex occupied what is now Clear Lake (Figure 1-3). Water from this lake drained into the Lost River and then to Tule Lake (USBR 2000a). In most years, the Lost River below the present Clear Lake dam ran dry from June through October. To hold back floodwaters from Tule Lake and store seasonal runoff for irrigation later in the season, a dam was constructed at Clear Lake in 1910, impounding the waters of the Lost River and creating a larger lake.

Where Gerber Reservoir now stands (Figure 1-3), 3500 acres of seasonal wetlands existed before the Klamath Project, but there was no lake. Construction of Gerber Reservoir in 1926 for flood control and irrigation created new sucker habitat and a population of suckers persists there (USBR 2002b, Chapter 5).

AQUATIC ENVIRONMENTS IN THE LOWER KLAMATH BASIN

The lower Klamath River, including the Trinity River, is the largest of the coastal rivers of California (Figure 1-1). The lower Klamath basin historically was dominated by large runs of anadromous fishes with diverse life-history strategies (Chapter 7), some of which penetrated into the headwaters of tributary streams and into the rivers feeding Upper Klamath Lake. Four major tributaries to the Klamath River—the Salmon, Scott, Shasta, and Trinity rivers—were major salmon and steelhead producers. The Shasta River in particular, with its cool summer flows, was once one of the most productive streams of its size for anadromous fish in California (Chapter 7).

Historically, most of the aquatic habitat in the lower Klamath River consisted of streams with moderate to high gradients and cool water in summer, although the mainstem Klamath River may have been fairly warm during late summer. Similar conditions existed in the Trinity River (Moffett and Smith 1950). The flows in tributary streams were high in winter and spring from rain and snowmelt and low in summer. Native fishes of the lower basin are mainly anadromous but also include a few nonanadromous stream fishes (Chapter 7).

Many small tributaries enter the mainstem Klamath between Iron Gate Dam and Orleans. These creeks largely drain mountainous watersheds dominated by forest. Most creeks are affected to some degree by logging, mining, grazing, and agriculture. Water withdrawal leads to reductions in summer base flows in many of these tributaries. Water quality has not been extensively studied, but these tributaries may be particularly important in providing cold-water habitats for salmonids (Chapter 4).

As described below, the watershed has been drastically altered by human activities. The anadromous fishes have been in decline since the 19th century, when dams, mining, and logging severely altered many important streams and shut off access to the upper basin. The declines continued through the 20th century with the development of intensive agriculture and its accompanying dams, diversions, and warm water. Commercial fishing also contributed to the declines.

HISTORY OF LAND USE IN THE KLAMATH BASIN

For at least 11,000 yr, ancestors of the Klamath and Modoc Indians inhabited the upper Klamath basin (OWRD 2000). Most of the year, the Klamath and Modoc tribes lived near creeks, springs, riparian areas, and marshes (Cressman 1956). Their family groups were small, so they were able to extract enough resources for survival on a sustainable basis. Family groups came together during seasons of resource abundance for communal hunts, for celebrations, and to take advantage of seasonal concentrations of suckers and riparian plants (Cressman 1956).

The Klamath Indian name for Lost River suckers is *tchwam*; shortnose suckers are referred to as *kuptu* (L. K. Dunsmoor, Klamath Tribes, Chiloquin, Oregon, personal communication, September 3, 2002). Suckers in general became known to settlers as mullet. Lost River suckers in particular were once a staple food of the Modoc and Klamath tribes; they provided important protein in the spring, when food reserves had been depleted (Cope 1879, USFWS 2002). Gilbert (1898) reported them as the most important food fish in the Klamath Lake area, and Stern (1965) estimated an artisanal harvest of 50 tons/yr, which would correspond to 13,000 fish at an average weight of 3 kg.

The Klamath and Modoc tribes manipulated the wetlands and riparian areas to increase their resources. For example, the Klamath burned riparian areas because women preferred to weave baskets with the supple young stems that sprouted after a fire. They burned wet meadows in fall to increase production of root plants, to lure animals that were attracted to the protein-rich shoots that grew after fire, and to protect their shelters from wild grassland fires. Intensive digging, particularly for roots, also altered riparian areas (C. Burnside, Malheur National Wildlife Refuge, personal communication, 1997).

Four tribes occupied the lower Klamath basin. The Yurok lived along the Pacific coast from about 15 mi south of what is now Crescent City down to Trinidad Bay and up the Klamath River to Bluff Creek, a few miles past the junction with the Trinity River. The Hupa people lived along the Trinity River, where 13 villages were concentrated in a 7-mi reach called Hoopa Valley. The Karuk lived along the Klamath River upstream of the Trinity to a point beyond Happy Camp. Above Happy Camp, the Shasta Nation occupied the upper reaches of the Salmon, Klamath, Scott, Shasta, and McCloud rivers (Beckman 1998).

The Yurok, Hupa, and Karuk were closely allied with the sedentary cultures of the northwest coast; the Shasta showed cultural traits more akin to those of the migratory tribes of the inland West (Beckman 1998). The Yurok, Hupa, and Karuk spoke languages of three very different language groups—Yurok is Algonquian, Hupa is Athapaskan in origin, and Karuk is Hokan and thus associated with old languages of Mexico—but their cultural habits were similar (Beckman 1998). In contrast with the tribes down river, the Shasta did not occupy permanent villages, and their traditions were closer to those of the tribes of the upper Klamath basin.

The Yurok and Hupa, unlike tribes in the drier inland regions, were able to be almost completely sedentary because of salmon runs (Nelson 1988). As Beckman (1998) noted, their resources were so plentiful that they had the free time to nurture the arts and crafts in a way that was uncommon in California and that gave them a hierarchy of status and wealth. Unlike most other California nations, the Yuroks recognized no chiefs and had no organized political society. They were unique in believing in individually owned land; a family's wealth was measured by the amount of land that it owned, and land could be sold. The Hupa were strictly a river people, whereas the Yurok were divided between river and coastal villages. Most Yurok, however, lived along the Klamath River and relied on riverine resources (Waterman 1920), even though they used coastal resources, such as shellfish, surf fish, and seals. Anadromous fish that brought the abundant energy of the Pacific Ocean upstream were the Yurok's, Hupa's, and Karuk's most important resources and were critical resources for the Shasta as well.

Fur Trapping

When fur trappers from the Hudson Bay Company of Canada arrived in the Klamath basin in the 1820s, tribes throughout the basin coexisted in relative peace with them. Trappers were not seeking to establish permanent settlements in the basin that might threaten tribal rights. Rather, in an attempt to discourage Americans from laying claim to the region, Hudson Bay Company's written policy was to trap fur-bearing animals from streams south of the Columbia River to extinction. In July 1827, George Simpson of the Hudson Bay Company stated the policy clearly, writing that the best protection from Americans was to keep the "country closely hunted" (Williams 1971, p. xiv). Peter Skene Ogden, the trapper who opened up much of the basin to white exploration, followed that policy. By the summer of 1828, Ogden wrote of the region that "almost every part of the country is now more or less in a ruined state, free of beaver" (Ogden 1971, p. 98). During the next spring, he wrote that "it is scarcely credible what a destruction of beaver by trapping at this season, within the last five days upwards of fifty females have been taken and on average each with four young ready to litter. Did we not hold this country by so slight a tenure it would be most to our interest to trap only in the fall, and by this mode it would take many years to ruin it" (Ogden 1971, p. 17).

Ironically, it was the removal of beaver by fur trappers that helped create the basis for ranching. When beaver were removed, their dams fell into disrepair and the small wetlands behind the dams were drained and became the fertile meadows that were soon to sustain ranchers' cattle (Elmore and Beschta 1987).

Mining

Although the tribes were able to coexist with trappers, the miners who followed them proved disastrous to the Indian nations. Far more than trappers, miners transformed the basin's rivers and wetlands, partly because of mining activities in the rivers and streams and also because of their indirect encouragement of permanent white settlements. Miners created a new market for food and supplies and thus attracted farmers and ranchers to the region. Many of the settlements in the lower Klamath River basin originated from the mining boom of the middle 1800s (NMFS 2001). Miners also depended upon federal troops and Indian agents to cope with the problems that mining generated; they created a U.S. Army presence in the basin that further destabilized relations with the tribes (Malouf and Findlay 1986).

Mining in the 19th century was particularly destructive of fish habitat along the lower Klamath basin. In 1853, miners discovered a way to excavate gold-bearing placer deposits by using blasts of water to wash away gravel. Mining companies soon diverted creeks into reservoirs that fed water at high pressure to huge nozzles that could deliver water at up to 30,000 gal/min. The jets of water could level entire hillsides and their use rearranged much of the riparian landscapes of California. The waterborne debris was directed into sluices containing mercury, which captured the gold. Before a court ruling halted the practice in 1884, hydraulic miners released 1.6×10^9 yd^3 of sediment into California waterways, while hard-rock miners produced another 3×10^7 yd^3 of tailings, and dredgers left behind about 4×10^9 yd^3 of debris—a total of about 5.6×10^9 yd^3 for the entire state (Krist 2001).

Water was diverted and pumped for use in sluicing and hydraulic operations that resulted in increased turbidity and siltation. Silt from mining harmed benthic invertebrates, covered salmon redds, suffocated salmon eggs, and filled pools that were used by salmon. Wood for equipment and structures, railroad tracks, housing, and fuel was obtained through deforestation, often on steep slopes, and caused erosion, flooding, fires, and loss of animals. Miners also reduced freshwater resources by overfishing, damming, and diverting streams (Malouf and Findlay 1986).

The gold rush brought extensive changes to the Scott River watershed, particularly the main stem and South Fork and Oro Fino, Shackleford, and French creeks. Placer mining began as early as 1851 and expanded to widespread hydraulic mining in 1856 (Wells 1881). Large Yuba dredges that operated in 1934-1950 (Sommerstram et al. 1990) left some of the most visible effects of mining in the basin. They excavated material 50-60 ft below the river bed and created tailings piles more than 25 ft high downstream of the town of Callahan. The processing of the sediment by Yuba dredges left much of the coarsest material (typically boulders) at the top of the piles, effectively armoring the finer sediments. Early surveys in the basin (Taft and Shapovalov 1935) noted the severe damage that the dredging had caused to fish habitat. To support the mining, numerous ditches were constructed along the margins of the valley to intercept tributary flows, and these ditches eventually became sources of irrigation water for early agricultural development.

The Salmon and Trinity rivers were also severely affected by mining. Along the Salmon River, during the late 1800s and into the 1990s, extensive placer gold mining and some hydraulic gold mining were conducted in the main stem and the South and North Forks. The main stem of the Trinity River was severely impaired by placer mining within the channel and by hydraulic mining and extensive dredging.

One of the most problematic effects of the gold rush was the release of mercury into the environment; the consequences continue today. Mercury was critical in the mining and processing of gold; it is estimated that at least 2.6×10^7 lb of elemental mercury were used between 1850 and 1900 in gold mining. Much of the mercury remains in soils and sediments, and some of it has been converted into methyl mercury, which is particularly dangerous for humans because it travels through the food chain into fish and becomes a threat for those who eat fish. In addition to contamination from mercury used in gold mining, mercury contamination comes from mercury mines, some of which were in the Klamath basin. Most of the mines are now abandoned (Krist 2001).

By the late 1850s, gold mining in California was a large-scale industry that required infusions of capital for construction of mills, rail lines, dams, flumes, and smelters. Miners used two major processes to extract gold: stamp mills and hydraulic placer mining. Both methods used a great deal of mercury. Stamp mills pounded gold-bearing ore into dust that then was washed across mercury-coated plates; the gold sank and stuck to the mercury, and the less dense debris was carried away. The mercury-gold amalgam then was heated in furnaces, which vaporized the mercury and left the gold. Some of the evaporating mercury was captured in a condensation chamber for reuse, but much escaped into the air or was crushed by the stamp mill and released into the water. Hydraulic placer mining released even more mercury into the environment--perhaps as much as 1 lb of mercury for every 3 or 4 oz of gold recovered, or about 1.3×10^7 lb of mercury in the 19th and early 20th centuries (estimate by Ronald Churchill of the California Division of Mines and Geology, cited in Krist 2001).

Because salmonids achieve most of their growth in the marine environment, mercury accumulation in adult salmon presents less of a health risk to humans than would mercury accumulation in other kinds of large predatory fish. Nevertheless, mercury contamination may affect the coho salmon themselves. Young salmon are sensitive to mercury released by placer mining (USFWS 1991). Early life stages of coho salmon are harmed by low concentrations of methyl mercury (Buhl and Hamilton 1991, Devlin and Mottet 1992), and placer mining releases contaminants that can be toxic to early life stages of salmonids (Buhl and Hamilton 1990).

The deleterious effects of mining on salmonid habitat were so rapid and intense that in 1852, only 4 yr after Sutter's discovery of gold in the foothills of the Sierra Nevada, California enacted its first salmon statute, which required "'all good citizens and officers of justice' to destroy man-made obstructions to salmon migration, except those erected by Indians." That statute did little to stem habitat destruction. In the 1880s, all obstructions to salmon migration, including those built by Indians, were banned by state law (Lufkin 2000).

The gold rush struck all California tribes hard (Heizer 1978, White 1991). Within a year after Sutter's 1848 discovery, at least 80,000 miners and others came to California, overwhelming governmental and military authority. In the quarter-century from 1845 to 1870, the Indian population in California declined from about 150,000 to 30,000 largely because of direct and indirect effects of the gold rush (Franzius 1997).

In 1851-1852, 18 treaties were negotiated with California tribes, including the Yurok, Hupa, and Karuk. The treaties set aside 7,466,000 acres of lands for the tribes and promised agricultural and educational assistance. But in 1852, California's new state senators refused to ratify the treaties.

Among the tribes of the lower Klamath basin, violent resistance to miners and to the California legislature's increasingly repressive policies erupted in 1860-1872. The Hupa were more successful than many other California nations in resisting encroachments of settlers on their land. When federal troops entered the Hoopa Valley, the Hupa were able to withstand the troops and force them into a stalemate. On August 12, 1864, the Treaty of Peace and Friendship was signed between the Hupa and the U.S. government; it promised the Hupa a reservation that included about 90% of their original homeland. In 1891, President Harrison signed an executive order joining the Hupa and Yurok reservations. The Karuk and Shasta, however, never gained legal ownership of their homeland. Most land occupied by the Karuk was claimed by the government with little compensation, and much of it became part of the national forest system. Timber development in the 20th century brought some measure of prosperity to the Hupa and Yurok reservation. For example, seven new sawmills were constructed in the Hoopa Valley during the 1950s, and timber income was distributed throughout the tribe. Yet this was also the "Termination Era," when federal Indian policy shifted toward the termination of tribal rights and the breakup of Indian land holdings (Nelson 1988).

As miners, ranchers, and the army came to the Klamath basin in the 1850s, confrontations erupted, culminating in the Modoc Indian War of 1872. In 1864, the Klamath and Modoc tribes and the Yahooskin band of Snake Indians met with federal officials to sign a treaty that relinquished more than 19 million acres of their homeland, reserving about 2.5 million acres for the Klamath Indian Reservation. This land was soon substantially reduced through correction of a federal survey error (Gearheart et al. 1995). The treaty of 1864 specified the Klamath Tribes' exclusive right to hunt, fish, and gather on Klamath Indian reservation lands. Although the Klamath tribes lost their reservation land following termination of the reservation in 1954 (Haynal 2000), they retained their water rights and their right to harvest a number of fish species designated as tribal trust species, reflecting their traditional practices.

Ranching

After the Modoc Indian War, open hostilities between whites and Indians diminished in the upper basin, and white immigration to the basin increased. Early white settlement in the upper Klamath basin centered on ranching rather than farming because without irrigation, precipitation often was insufficient for growing most crops (Blake et al. 2000). The General Allotment Act of 1887 allowed Indian lands to pass into white ownership, and much of the best grazing land on the reservation was bought by whites.

In the upper Klamath basin, as throughout the entire inland portion of the West, cattle increased in abundance during the 1870s and 1880s until by the late 1880s overgrazing became a political and ecological issue. In 1875, the Central Pacific Railroad completed a shipping facility at Winnemucca, Nevada, giving cattle operations relatively rapid access to San Francisco beef markets. With an efficient transportation infrastructure in place, ranchers brought more animals to the open range. When prices were low, few ranchers sold their young cattle, and herd sizes rose while ranchers waited for better prices (Gordon 1883). Overgrazing was the result.

The federal government responded to overgrazing with the Gordon report, the product of a study motivated in part by the disastrous winter of 1879-1880, when extraordinary cold led to high mortality of cattle across the West. Gordon noted that overgrazing meant that wetlands and riparian meadows were becoming critical habitat for cattle, especially in southeastern Oregon. Ranchers fenced riparian areas and planted them with alfalfa for winter feed. That took some of the pressure off the land, but only for a short time (Gordon 1883). The result, as the 1883 edition of *West Shore* magazine reported, was a landscape "almost bare of grass except for a few clumps under the dense, scraggly sage brush" (Lo Piccollo 1962, p. 115).

In the wake of the 1879-1880 disaster, cattle and sheep populations were rebuilt until a combination of dry summers and cold winters occurred in the late 1880s (Simpson 1987). Cattle prices collapsed in 1885 and 1886, and ranchers held their stock from market, hoping for higher prices. In 1889, when the geologist Israel Russell toured southern Oregon, streams throughout the region that Ogden had described as level with the surrounding landscape in the 1820s had begun to incise their channels, and Russell (1903, p. 63) concluded that this was caused by "the introduction of domestic animals in such numbers that the surface covering of bunch grass was largely destroyed, and in consequence the run-off from the hills accelerated."

Government inspectors who were sent to the region warned that overgrazing was ruining the very source of the region's prosperity. The inspectors recommended that the only solution was to provide more grass by draining wetlands and planting them with hay so that there would be less competition for a dwindling resource (Griffiths 1902). Ranchers did exactly that as they began diking and draining wetlands in the 1890s along the borders of Upper Klamath Lake to provide more forage for cattle.

Good government records of numbers of cattle in the upper Klamath basin begin with the 1920s, when 30,000 cattle occupied Klamath County, which makes up only part of the watershed (Walker 2001). In the 1960s, the cattle population in Klamath County peaked at 140,000 head (Figure 2-2); by 1999, there were 120,000.

To accommodate cattle, ranchers turned to flood irrigation of pastures and drainage of wetlands. Early methods of flood irrigation did not always degrade riparian and wetland habitat, but a switch to nonnative species for production of hay in the 1950s required changes in irrigation practices that, while increasing efficiency, severed riparian connections to the landscape (Langston 2003). In 1998, the Environmental Protection Agency's Index of Watershed Indicators estimated that at least 110,000 acres of the watershed had been converted to irrigated pasture or other agricultural activities; Risley and Laenen (1999) estimated an 11-fold increase in acreage of irrigated land between 1900 and the 1990s.

While numbers of cattle were only slightly lower in the 1990s than in the 1960s, the acreage of land being grazed declined much more substantially. The U.S. Bureau of Reclamation (USBR) estimated that by 2000 only 35% of the Upper Klamath Lake watershed was grazed (USBR 2002a). By 2002, nearly 100,000 acres of irrigated agriculture had been retired, and some of this was restored to wetland. Thus, production intensity appears to have increased. Transport of cattle to California during the winter was part of the method for keeping cattle production high while the acreage of irrigated pastureland declined.

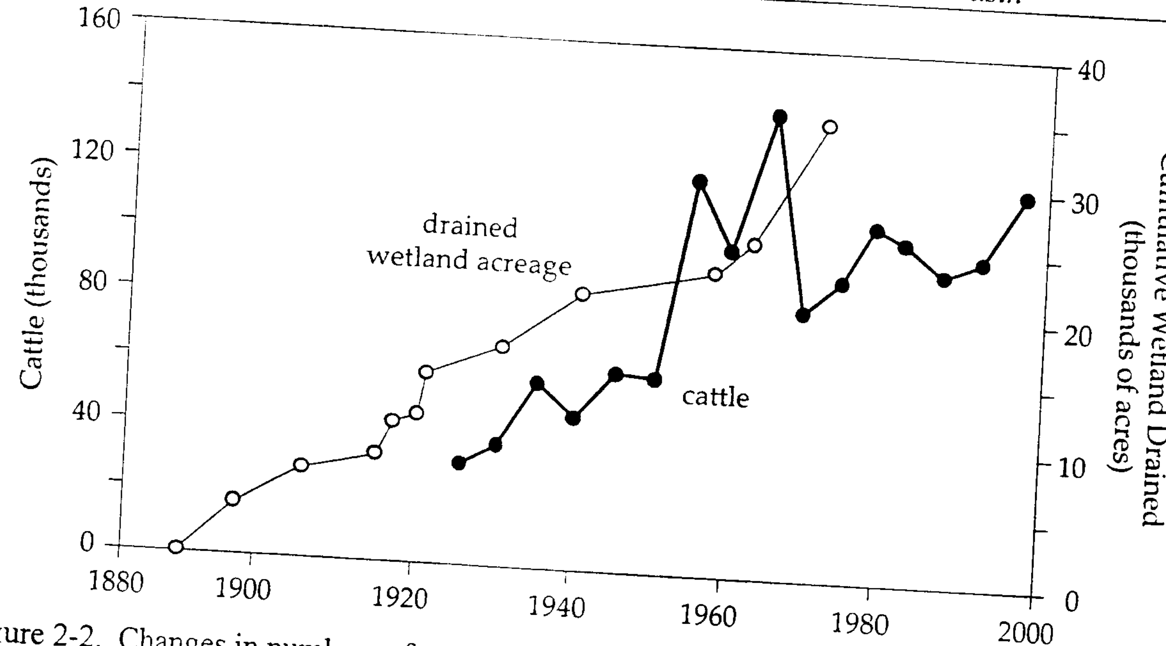

Figure 2-2. Changes in numbers of cattle and cumulative acres of drained wetland in Klamath County, Oregon. Source: modified from Eilers et al. 2001.

The effects of grazing in the watershed were probably profound but are impossible to quantify. Overgrazing in riparian zones can harm fish by degrading riparian vegetation (Chapter 4). Grazing can mobilize nutrients and sediments, both of which are of concern in the upper Klamath basin (Stubbs and White 1993). By 1900, native perennial grasses were being replaced with annual grasses and forbs that, when combined with soil compaction from cattle, may have resulted in higher erosion and greater peak flows (NMFS 2001). For example, on Fishhole Creek, cattle had destroyed streambank vegetation, resulting in erosion and lowered water tables (Thompson et al. 1989). Conditions are similar in the Wood River valley and in some of the Sprague River watershed. Season-long grazing in the past probably contributed to reduction of spawning habitat for trout and suckers in the Sprague River, increased stream temperatures, and increased transport of sediment and nutrients. These changes led the Oregon Department of Environmental Quality to identify the Sprague River as one of the highest-priority streams in Oregon for control of non-point-source pollution (Stubbs and White 1993). Cattle do not always lead to such adverse effects; well-managed riparian pastures can be consistent with good stream conditions.

Irrigated pasture required water diversions from Klamath basin tributaries, and the diversions have played a substantial role in the decline of suckers in the upper basin and of salmonids in the lower basin (Chapters 5 and 7). The Chiloquin Dam on the Sprague River near Chiloquin, Oregon, constructed in 1914-1918 for water diversion and timber milling, is one example.

Timber

Much of the blame for poor watershed conditions is placed on agriculture, but nearly 80% of the Upper Klamath Lake watershed is forested, and much of the forest land has been harvested under federal, tribal, and private management (Gearheart et al. 1995). According to the Oregon State Water Resources Board (cited in Gearheart et al. 1995), over 73% of the forest land in the upper Klamath basin is subject to severe erosion. Therefore, timber management may well have contributed to the decline of suckers and salmonids.

Commercial logging began in the upper basin in 1863 when the U.S. Army constructed a sawmill. The pace of logging accelerated during the late 1910s, when ponderosa pine became an important timber resource for the nation (Langston 1995). By 1918, large amounts of reservation timber were being sold to private parties; by 1920, annual harvest rates had increased to 120 million board ft. Peak lumber production occurred in 1941, when 22 lumber mills processed a total of 808.6 million board ft within the upper basin. Harvest has dropped to about 400 million board ft in recent years (Eilers et al. 2001, Gearheart et al. 1995).

Poorly designed roads and damaging harvest practices on pumice and volcanic soils and on steep slopes probably contributed to loss of fish habitat. When stripped of vegetative cover, steep slopes are subject to erosion. In the lower basin, road construction has increased erosion and also created barriers to fish passage (USBR 2001b). Log storage on the Klamath River below Klamath Falls also has affected fish habitat. After fish kills in the late 1960s, log storage was greatly reduced on the river, but it continues (Stubbs and White 1993).

Forest management and fire suppression over the last century changed forest composition in the Klamath basin. The change may have altered flow regimes in the rivers and nutrient movement in the watershed. Before the 1920s, the upper basin forest was composed largely of old-growth ponderosa pine except at high elevations, and frequent, low-intensity fires minimized understory growth. Logging and fire suppression have led to a much denser understory populated with grand fir (Risley and Laenen 1999). As forest composition has changed, the risk of intense fires has increased substantially. Such fires can contribute damaging amounts of sediments and nutrients to streams and rivers. Moreover, intensive clearcutting may have increased peak flows, and the increased understory and denser forests may have decreased total water yield (Risley and Laenen 1999).

In the lower Klamath basin, timber harvesting began in the 1850s in the Scott River watershed commensurate with the growth in mining. As in most northern California watersheds, logging activity reached a peak in the 1950s (Sommerstram et al. 1990). The construction of roads and trails in the watershed has been a major source of fine sediment in the basin, particularly on decomposed granite soils. About 40% of the Scott River watershed that is underlain by such soils was harvested in 1958-1988; more than 288 mi of logging roads and 191 mi of skid trails were constructed (USFS data, summarized in Sommerstram et al. 1990). Sediments have adversely affected spawning and rearing habitat of coho (West et al. 1990).

Along the Salmon River, logging has been substantial, particularly since the 1950s. Road networks have been identified by the U.S. Forest Service (USFS) and the California Department of Fish and Game (CDFG) as an important source of sediment in the basin, and road crossings have been identified as affecting salmonid habitat (CDFG 1979a). Also, the heavily forested Salmon River watershed is susceptible to large wildfires. Since the early 1900s, more than 50% of the basin has burned, and most of the fires have been intense crown fires (USFS data, summarized in Salmon River Restoration Council 2002). Although poorly funded, federal fuel-management efforts are under way in the basin in cooperation with the Salmon River Watershed Council.

In the Trinity River watershed, logging practices, described as "abusive" by the Secretary of the Interior in a 1981 decision regarding flow releases on the Trinity, has had significant effects on the quality of salmonid habitat on the Trinity (USFWS/HVT 1999). Extensive logging road networks, coupled with highly erosive soils, have produced high yields of fine sediment within the basin. Very large floods on the Trinity River in December of 1964 introduced especially large volumes of fine sediment that caused severe degradation of spawning and rearing habitat in the South Fork and main stem of the Trinity.

Agriculture in the Upper Basin

Serious efforts at irrigation and drainage in the Klamath basin started in about 1882; by 1903 about 13,000 acres in the upper Klamath basin were irrigated by private interests. Land speculators urged USBR to consider the Klamath basin for irrigation, and a USBR engineer estimated in 1903 that irrigation could water 200,000 acres of farmland.

California and Oregon had acquired Lower Klamath Lake through the Swamp Lands Act of 1860, but their efforts to stimulate drainage and reclamation had failed. In 1904 and 1905, California and Oregon ceded the lake back to the federal government for use by USBR. Oregon gave USBR the right to the water of the Klamath River (Jessup 1927). In February 1905, Congress approved the Klamath Project, and work began.

USBR engineers focused their early efforts on Lower Klamath Lake and Tule Lake. The project would dry up these two lakes so that the land under them could be farmed. The government would then construct two new lakes to hold water for irrigation (behind Clear Lake and Gerber dams, Figure 1-3). A dam and canal would divert the Lost River to the Klamath River. Headworks would take water from Upper Klamath Lake into an elaborate irrigation system. USBR would fund construction of irrigation works; people (mostly veterans) would buy land irrigated by those works from the federal government in parcels of up to 80 acres and would pay for the land and improvements over 10 yr. The federal government sold the land, but not the water rights, to Klamath Project irrigators; irrigators were promised use of sufficient water for irrigation each year for a modest fee.

Meanwhile, just three months after Congress authorized the Klamath Project in early 1905, conservationists discovered the basin's extraordinary abundance of avian life. During the summer of 1905, just a few months after Congress approved the Klamath Project, the conservationist William Finley toured the marshlands in the lower Klamath basin. He was awed by what he found, including extraordinary concentrations of pelican rookeries and what he believed to be the greatest feeding and breeding ground for waterfowl on the Pacific Coast. By 1908, Finley had persuaded President Roosevelt to create the Lower Klamath Lake National Wildlife Refuge (Figure 1-3), thus preserving nesting grounds for migratory waterfowl. It was to be one of the largest wildlife refuges ever authorized, one of the first on land of any agricultural value, and the first to be established in a watershed being transformed by USBR. In 1911, President Taft established the Clear Lake National Refuge and in 1928 President Coolidge established Tule Lake National Wildlife Refuge. The Biological Survey would manage the refuges, and land within refuge boundaries would not be made available for settlement.

President Roosevelt's designation created inherent conflicts. The refuges were to be managed by the Biological Survey, which could not function with full independence because the refuges were on land of USBR, which also controlled the water reaching the area. To USBR, wetlands and riparian areas were wastelands waiting for conversion (reclamation) to agriculture (Langston 2003).

President Roosevelt had intended no settlement within the boundaries of the refuge, but USBR interpreted refuge boundaries as encompassing only land covered by water all year. Thus, if USBR drained the lakes and wetlands, it would no longer be refuge land, and it could be sold or leased.

Before draining Lower Klamath Lake, USBR commissioned soil surveys to see whether the area would be good farmland. C. F. Marbut, a government soil scientist with the U.S. Department of Agriculture (USDA), completed a report indicating that the lakebed would be utterly worthless for agriculture. "We can not cite an example of the successful cultivation of a soil of similar character," admitted Copley Amory, an economist with USBR, in response to that discouraging report (Amory 1926, p. 80). Moreover, the report stated, wetlands surrounding the lake would have only a slim chance of supporting agriculture because the underlying peat, once drained, would be subject to smoldering fires and subsidence.

Despite Marbut's report, USBR authorized $300,000 for drainage of Lower Klamath Lake. Conservationists challenged USBR's plans in court, and President Wilson in 1915 reduced the Lower Klamath Lake National Wildlife Refuge from 80,000 acres to 53,600 acres, freeing up the rest for drainage and sale or lease.

The federal government signed an agreement with railroad companies according to which the companies would construct an embankment across the marshes with a gate that would close Klamath Straits. The gates were closed in 1917, cutting off flow of water from the Klamath River into the lake (Jessup 1927). Within a year, the flooded area of the lake decreased by about 53%, from 76,600 acres to 36,000 acres; within 5 yr, most of the waters of the lake had evaporated (Weddell 2000). USBR entered into contracts in 1917, first with California-Oregon Power Company, selling it water rights to the river for power generation, and then to a drainage and land-speculation company, the Klamath Drainage District. The shrinkage of the lake greatly reduced waterfowl populations. The peat beds of the wetlands began to burn and collapse, farm efforts failed, and, by 1925, homesteaders were going bankrupt. By 1925, nearly everyone involved agreed that the project was a failure.

After USBR had drained Lower Klamath Lake, it leased what remained of the refuges for grazing. The ornithologist Ira Gabrielson (1943, p. 13) described the situation in 1920:

> The water table on the lake has been lowered several feet by closing the gates which control the inflow from the Klamath River. This action, made under agreement with the water users' association, has uncovered large areas of alkali flats without thus far benefiting the settlers adjoining the lake or opening up additional land suitable for agriculture. Its future as a refuge is seriously jeopardized. This is an understatement of the wildlife tragedy involved in the loss of one of the two greatest waterfowl refuges then in existence.

Near Tule Lake National Wildlife Refuge, water from drained wetlands was being pumped into headwater ditches, used for irrigation, and then collected in the Tule Lake Sump on the refuge, where it was allowed to evaporate. Farmers wanted the land under the sump for farming, but the Tule Lake Sump was overflowing with irrigation return flows as more and more farmers irrigated reclaimed lands.

A reclamation engineer, J. R. Iakish, proposed to pump the irrigation return flows from the Tule Lake Sump through a 6600-ft tunnel beneath the ridge to Lower Klamath Lake to put out the fires and restore the wetland. Such a plan, Iakish argued, would create more farmland by draining the sump and more wetland for birds by putting out the fires on Lower Klamath. In 1941, the tunnel was finished, and in the next year, water flowed once again into Lower Klamath Lake. Some of the Lower Klamath Lake wetlands began to refill, and some of the abandoned farmlands were reclaimed when developers figured out how to use the irrigation wastewater, in conjunction with deep drains, to leach alkali out of soils. Lower Klamath, people argued, could indeed be farmed profitably, so waters intended for restoration were instead used for farming (Blake et al. 2000).

In 1946, USBR authorized new allotments on lands north of Tule Lake (shrunk by use of the tunnel) and held a lottery drawing for World War II veterans. The federal government urged thousands of veterans to apply for these new homesteads, promising them as much water as they would ever need for irrigation. Some of the land on the refuges was given to veterans. A total of 22,000 acres was leased to farmers for agriculture in what became known as the lease-land program. For example, nearly half the 39,000 acres of the Tule Lake National Wildlife Refuge became cropland (Kemper 2001). Japanese and Japanese-American citizens who had been interned at the Tule Lake Camp during World War II were the first to farm much of this land, and their labor helped make it ideal farmland for returning veterans.

Agriculture in the Lower Basin

During the early 1900s, farmers and ranchers removed riparian vegetation and valley forests along the lower Klamath River and its tributaries (CDFG 1934). For example, the U.S. Army Corps of Engineers, in conjunction with the National Resource Conservation Service (then known as the Soil Conservation Service), conducted a series of projects on the main stem and tributaries of the Scott River, including removal of riparian vegetation on the middle reaches of the valley, drainage of remaining wetlands, and construction of a series of flood-control and bank-stabilization projects (Scott River Watershed CRMP Council 1997). Today, the Scott Valley supports more than 30,000 acres of farms and irrigated pasture (CDWR, Red Bluff, CA, unpublished material, 1993; Scott River Watershed CRMP Council 1997). The principal crops are alfalfa (33,000 acres) and grain (2000 acres). There are 153 registered diversions in the Scott Valley; 127 are listed by the Siskiyou County Resource Conservation District (SRCD) as active. Fish screens have been installed on 65 of the diversions; another 38 have been funded but not yet built.

In the Shasta River watershed, after the gold rush in the late 1800s, most of the land cover of the Shasta Valley was converted for agriculture and range. About 28% of the watershed is irrigable land that supports a mix of alfalfa, irrigated pasture, and some grain (CDWR 1964). Nonirrigable land supports range and limited dryland farming. The mix of agricultural uses has remained relatively constant in the basin. Mining and timber harvesting are limited and do not substantially affect the river. Significant urbanization, however, is taking place in the watershed. Most development is occurring in the vicinity of Yreka, the county seat of Siskiyou, and Montague, in the northern portions of the Shasta Valley. There is also increasing pressure to develop in the upper watershed, particularly around the town of Weed and near Lake Shastina (Dwinnell Dam).

FISHING AND ATTEMPTS TO REGULATE LOSS OF FISH

Mining, timber management, dams, and agriculture have degraded fish habitat, but overharvesting also has affected fish populations (Chapters 5 and 7). In the upper Klamath basin, tribal harvests of suckers for family consumption were augmented by commercial harvests beginning in the 19th century, including a cannery that processed Lost River suckers captured from the Lost River near Olene, Oregon, in the late 1890s (53 Fed. Reg. 27130 [1988]). Before the drainage of Tule Lake and Sheepy Creek in the 1920s, suckers were taken in large numbers from Sheepy Creek for consumption by both humans and livestock (Coots 1965). A recreational snag fishery for suckers developed as early as 1909; it focused on fish that were moving into tributary rivers to spawn and secondarily on fish attempting to spawn around the edges of Upper Klamath Lake. The snag fishery remained unregulated until Klamath suckers were declared game species in 1959.

Commercial harvests of salmon intensified with the development of canning technology. Commercial harvesting of salmon began later in the Klamath River basin than in other basins in California and the Pacific Northwest partly because of the inaccessibility of much of the terrain. Nevertheless, by the early 20th century, habitat destruction combined with commercial harvests had resulted in serious salmon depletion on the Klamath River (Pacific Watershed Associates 1994). Cobb (1930) estimated that the peak of the Klamath River salmon runs occurred in 1912; Snyder (1931, p. 7) observed substantial declines in the 1920s. As Snyder observed, "in 1912 three [canneries] operated on or near the estuary and the river was heavily fished, no limit being placed on the activities of anyone."

Millions of juvenile coho salmon, Chinook salmon, and steelhead are released into the Klamath and Trinity rivers each year by the Iron Gate and Trinity River hatcheries, which were built to mitigate the salmonid losses created by large dams. These hatcheries were intended to maintain fisheries for coho and Chinook salmon, but they may have had adverse effects on wild populations of salmonids in the basin (Chapters 7 and 8).

WETLAND TRANSFORMATIONS

Even before the Klamath Project, the actions of humans in the upper basin were concentrated on wetlands. Cattle ranching had been concentrated on the margins of wetlands, extensive efforts to drain wetlands began in 1889, and drainage accelerated with the Klamath Project; restoration began in the 1990s. Figure 2-3 shows the cumulative drained acreage by year for Upper Klamath Lake. The drop in drained wetland acreage after 1990 reflects wetland

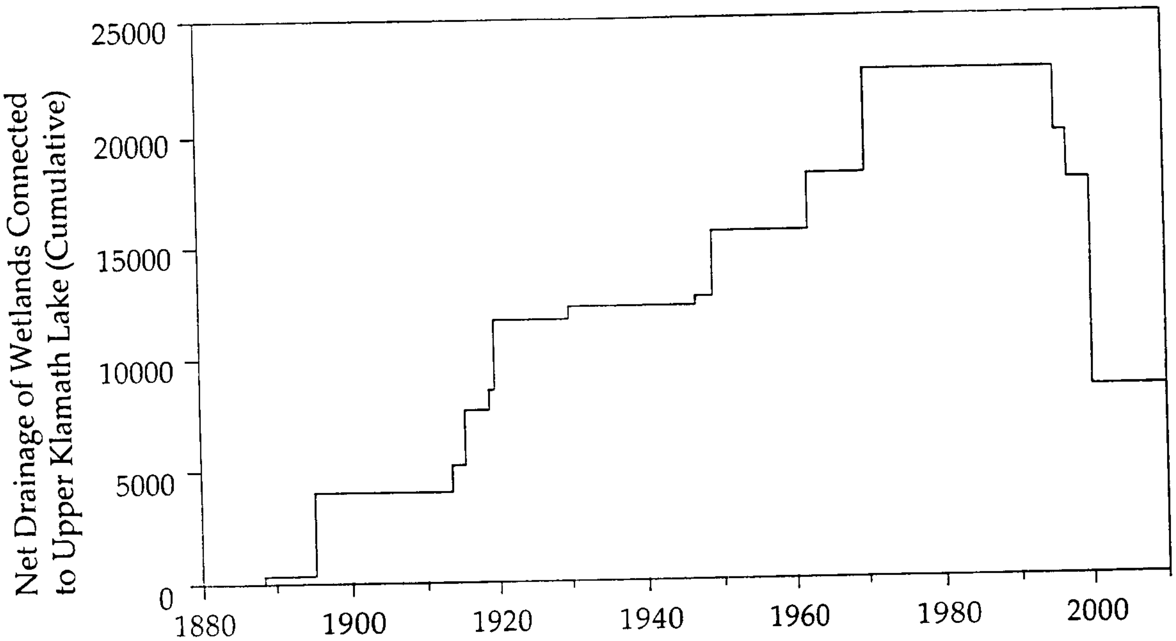

Figure 2-3. Net loss, through drainage, of wetland connected to Upper Klamath Lake. A decrease beginning in the 1990s indicates the effects of restoration. Source: modified from Boyd et al. 2001, p. 48.

restoration efforts in the upper basin. In Tule and Lower Klamath lakes, original wetlands were estimated at 187,000 acres; about 25,000 acres remain (Gearheart et al. 1995).

Reclamationists and farmers drained wetlands by building dikes to isolate them hydrologically, constructing a network of drainage ditches within them, and pumping surface water and shallow groundwater (Snyder and Morace 1997, Walker 2001). One effect of lowering the water tables in this way was an increase in aerobic decomposition of peat soils, which liberated nutrients and removed organic deposits. Disking and furrowing can introduce oxygen into the soils, and increase the rate of peat decomposition and nutrient release. Cattle grazing, in contrast, can compact drained soils and slow their decomposition (Walker 2001).

Some scientific work in the upper basin suggests that drained wetlands can become a substantial source of phosphorus (Snyder and Morace 1997), which can lead to increased nutrient loading in the Upper Klamath Lake (Bortleson and Fretwell 1993, Walker 2001). Extensive efforts to restore wetlands, partly to improve nutrient retention, have taken place in the upper basin in the last two decades. Above Upper Klamath Lake, an area of about 101,136 acres has been removed from irrigated agriculture and converted to artificial wetlands since the 1980s (E. Bartell, The Resource Conservancy, Inc., Fort Klamath, Oregon, unpublished report, 2002). The effects of these conversions on water quality are unclear.

Although wetlands of different types often are lumped in analyses of wetland change in the basin, different kinds of wetlands may have different effects on water quality. Geiger (2001) argues that wetlands in the littoral zone of Upper Klamath Lake may have had particularly important effects on water quality because they were connected to the lake and contributed humic substances that may have played a role in suppressing algae (see Chapter 3). Drainage efforts and subsidence have had pronounced effects on those wetlands. For example, the littoral wetland of Upper Klamath Lake once comprised 51,510 acres of the total lake area (46.2% at maximum elevation). By 1968, after diking and draining, littoral wetland had decreased to 17,370 acres (22.4% of total lake area). The littoral wetland area was reduced by 66.3%, and the wetland area at minimum storage volume (4136 ft vs the earlier minimum of 4140 ft) had shrunk from 20,320 acres to 0 acres (Geiger 2001). Some 34,140 acres of former wetland now is isolated behind dikes on Upper Klamath Lake. A total of 17,553 acres of former wetlands behind dikes is now being reclaimed, but subsidence has meant that, even after being restored, these areas remain disconnected from the lake and do not function as the littoral wetlands once did. Once dikes are removed, subsided areas become open-water habitat rather than littoral wetlands (Geiger 2001). Even so, reconnection of the littoral perimeter with open water would lead to the return of processes and functions that have been lost through severance of much of the littoral zone from the offshore areas of the lake.

The conversion of wetlands and associated channelization of riparian habitat have had deleterious effects on sucker habitat (Chapters 5 and 6). For example, sucker larvae historically moved through a meandering Williamson River into the delta area and the adjacent shoreline areas of Upper Klamath Lake. Since 1940, the Williamson River has been channelized, and the delta and adjacent shoreline have been diked and drained, leaving little of the wetlands and riparian vegetation (Klamath Tribe, Chiloquin, Oregon, unpublished material, 1993, cited in Gearheart et al. 1995). As a result, nursery areas have been greatly reduced. Larvae reach the lake sooner, exposing them to poor water quality at an earlier age and for longer.

Substantial wetlands remain in the basin. Klamath Marsh, a 60,000-acre basin underlain by pumice, is one example; 37,000 acres is protected as a federal wildlife refuge. A total of 23,000 acres of the Sycan Marsh was purchased by The Nature Conservancy in 1980 and is undergoing restoration. The largest wetland still connected to Upper Klamath Lake is Upper Klamath Marsh, a federal wildlife refuge on the northwest edge of Upper Klamath Lake; this refuge is the remnant of an emergent and open-water marsh system that once covered 60,000 acres of the Wood River valley (Gearheart et al. 1995).

THE ECONOMY OF THE KLAMATH BASIN

This section provides an overview, without conclusions or recommendations, of the structure of the economy of the Klamath basin on the basis of data from the Bureau of Economic Analysis (BEA) and the IMPLAN (impact planning) modeling process (Minnesota IMPLAN Group, Inc.). It is divided into discussions of the upper and lower basin economies, which differ substantially. Special attention is given to sectors of the economy oriented toward natural resources, including agriculture in both the upper and lower basin and commercial fisheries in the lower basin. It should be noted that this analysis only includes economic and employment values associated with commodities and services that are traded in markets. Non-market values, such as those associated with existence of species, preservation of environmental quality or maintenance of a particular life style, are not reflected directly in the economic values reported here.

Upper Basin

The upper Klamath basin includes parts of five counties in Oregon and California. Almost all the Oregon portion of the basin is in Klamath County, and the basin covers most of the county, including the county seat, Klamath Falls (population about 21,000), which is the major regional population center. In California, the basin covers the northwest corner of Modoc County, not including the county seat, Alturas (population, about 3000), and the northeast corner of Siskiyou County, including the county seat, Yreka (population, about 7500). The economy of the upper Klamath basin, which is home to about 120,000 people, in 1998 produced $4 billion worth of output, added $2.3 billion in value to purchased inputs, and had almost 60,000 jobs (Weber and Sorte 2002). This section, which is adapted by permission from Weber and Sorte (2002), describes the upper basin economy.

Over the last 30 yr, full- and part-time employment in the upper Klamath basin has increased from 40,000 to 60,000 jobs, while employment in Oregon as a whole has more than doubled. The composition of the regional economy has changed dramatically over that time. The sectors that grew most rapidly were wholesale trade and services (Table 2-2). Employment in several other sectors declined: military, transportation and public utilities, and manufacturing. Employment in farming, mining, and federal civilian employment grew, but increased more slowly than the regional average over the last three decades. Because of the more rapid growth in other sectors, the share of jobs in farming declined from 10.3% to 7.6%. Thus, over the last three decades, the basin's economy has grown slowly, has become more specialized in sectors that are growing rapidly in Oregon as a whole (services and wholesale trade), has shown little proportionate change in some slowly growing sectors (farming and federal civilian employment), and has become less specialized in other slow-growth sectors (manufacturing and transportation, public utilities).

Table 2-3 presents estimates of some basic economic indicators of the regional economy and their distribution among sectors for 1998. The four sectors with the largest shares of output in 1998 were wood products, consisting of forestry, logging, and manufacturing of wood products (15.5%); agriculture, consisting of food, beverage, and textile manufacturing (11.1%), construction (8.1%), and health care and social assistance (7.8%). The four sectors with the largest shares of value added were wood products (11%), retail trade (8.8%), real estate (8.7%), and public administration (8.6%). The four sectors with the largest employment shares were retail trade (11.1%), agriculture (10.7%), educational services (10.1%), and health care and social assistance (9.9%). These measures provide a perspective on the distribution of the regional economic activity among sectors. None of them identifies, however, how much the regional economy depends on each sector.

Table 2-4 summarizes the contribution of each sector to total regional employment and is based on an analysis using the upper Klamath basin input-output model. Such models use estimates of exports from each industry and multipliers for each sector to generate estimates of the dependence of the regional economy on each sector's exports. The procedure used to derive the estimates in Table 2-4 is described in Waters et al. (1999). The table compares the employment in a sector with employment that depends on a sector's exports. The jobs under "Sectoral Employment" are within the sector. The jobs under "Export-Dependent Employment" are from all sectors that depend on the exports from a sector. As an example, there were 4328

Table 2-2. Structural Change in the Upper Klamath Basin Economy, 1969-1999

Sector	Employment		Employment		Employment	
	1969	% of Total	1999	% of Total	Change 1969-1999	% Change
TOTAL FULL- AND PART-TIME EMPLOYMENT	40,392	100.0	60,101	100.0	19,709	48.8
Wage and salary employment	31,751	78.6	44,257	73.6	12,506	39.4
Proprietors' employment	8,641	21.4	15,844	26.4	7,203	83.4
Farm proprietors' employment	2,466	6.1	2,723	4.5	257	10.4
Nonfarm proprietors' employment	6,175	15.3	13,121	21.8	6,946	112.5
Farm employment	4,144	10.3	4,592	7.6	448	10.8
Nonfarm employment	36,248	89.7	55,509	92.4	19,261	53.1
PRIVATE EMPLOYMENT	27,563	68.2	44,926	74.8	17,363	63.0
Agricultural services, forestry, fishing and other	1,090	2.7	1,678	2.8	588	53.9
Mining	70	0.2	71	0.1	1	1.4
Construction	1,442	3.6	2,528	4.2	1,086	75.3
Manufacturing	7,171	17.8	5,883	9.8	-1,288	-18.0
Transportation and public utilities	3,084	7.6	2,474	4.1	-610	-19.8
Wholesale trade	876	2.2	2,388	4.0	1,512	172.6
Retail trade	6,291	15.6	10,213	17.0	3,922	62.3
Finance, insurance and real estate	1,965	4.9	3,573	5.9	1,608	81.8
Services	5,574	13.8	16,118	26.8	10,544	189.2
GOVERNMENT AND GOVERNMENT ENTERPRISE	8,685	21.5	10,583	17.6	1,898	21.9
Federal, civilian	1,665	4.1	1,856	3.1	191	11.5
Military	2,369	5.9	30	0.5	-2,049	-86.5
State and local	4,651	11.5	8,407	14.0	3,756	80.8

Source: modified from Weber and Sorte 2002.

Table 2-3. Output, Value Added, and Employment in the Upper Klamath Basin, 1998

Industry	Output $ Million	Output (%)	Value Added $ Million	Value Added (%)	Employment Jobs	Employment (%)
Agriculture and related[a]	320	7.9	169	7.3	5,964	10.0
Forestry and logging	30	0.7	16	0.7	248	0.4
Mining	4	0.1	2	0.1	33	0.1
Construction	327	8.1	119	5.1	3,357	5.7
Manufacturing—food, beverages, textiles and related	128	3.2	20	0.9	407	0.7
Manufacturing—wood products, paper, furniture and related	598	14.8	241	10.3	4,328	7.3
Manufacturing—high technology and related	17	0.4	3	0.1	94	0.2
Manufacturing—other (for example, sheet metal products)	113	2.8	35	1.5	844	1.4
Transportation and warehousing	263	6.5	139	6.0	2,257	3.8
Utilities	128	3.2	80	3.4	429	0.7
Wholesale trade	142	3.5	97	4.2	2,036	3.4
Retail trade	235	5.8	205	8.8	6,568	11.1
Accommodation and food services	163	4.0	92	4.0	4,785	8.1
Finance and insurance	197	4.9	138	5.9	2,179	3.7
Real estate, rental, and leasing	279	6.9	202	8.7	1,535	2.6
Other services	186	4.6	84	3.6	3,733	6.3
Information	100	2.5	55	2.3	1,241	2.1
Administrative and support services, and so on	28	0.7	16	0.7	936	1.6
Arts, entertainment, and recreation	31	0.8	19	0.8	1,133	1.9
Health care and social assistance	316	7.8	194	8.3	5,859	9.9
Professional, scientific, and technical services	38	0.9	26	1.1	865	1.5
Educational services	182	4.5	170	7.3	6,010	10.1
Public administration	200	5.0	200	8.6	4,551	7.7
Inventory valuation adjustment	7	0.2	7	0.3	0	0
Total	4,032	100.0	2,327	100.0	59,390	100.0

[a]Technically, this is agriculture, fishing, and related. However, the IMPLAN database for the upper Klamath basin identifies only 48 of 5964 jobs (0.8%) in fishing. Thus, the sector is renamed "agriculture and related."
Source: Weber and Sorte 2002.

Table 2-4. Export Based Employment, Upper Klamath Basin, 1998[a]

Sector	Sectoral Employment		Export-Dependent Employment				
	No. Jobs	%	Direct	Indirect	Induced	Total	Dependency Index (%)
Agriculture and related	5,964	10.0	4,531	1,052	1,004	6,587	11.1
Forestry and logging	248	0.4	243	144	52	439	0.7
Mining	33	0.1	27	5	9	41	0.1
Construction	3,357	5.7	2,809	1,128	1,139	5,076	8.6
Manufacturing—food, beverages, and related	407	0.7	374	865	288	1,527	2.6
Manufacturing—wood products, paper, furniture, and related	4,328	7.3	3,089	2,126	1,803	7,018	11.8
Manufacturing—high technology, and related	93	0.2	30	24	11	65	0.1
Manufacturing—other (for example, sheet-metal products	844	1.4	728	320	272	1,320	2.2
Transportation and warehousing	2,257	3.8	1,103	518	619	2,240	3.8
Utilities	429	0.7	36	26	27	89	0.2
Wholesale trade	2,035	3.4	352	76	104	532	0.9
Retail trade	6,568	11.1	423	22	82	527	0.9
Accommodation and food services	4,785	8.1	1,541	189	227	1,957	3.3
Finance and insurance	2,179	3.7	139	35	43	217	0.7
Real estate, rental, and leasing	1,535	2.6	95	50	26	171	0.3
Other services	3,733	6.3	1,110	238	235	1,583	2.7
Information	1,241	2.1	143	49	48	240	0.4
Administrative and support services	936	1.6	48	6	7	61	0.1
Arts, entertainment, and recreation	1,133	1.9	27	5	3	35	0.1
Health care and social assistance	5,859	9.9	371	65	122	558	0.9
Professional, scientific, and technical services	865	1.5	77	10	23	110	0.2
Educational services	6,010	10.1	4,546	86	1,208	5,840	9.8
Public administration	4,551	7.7	4,551	34	1,492	6,077	10.2
Households (social security)	-	-	11,952	1,947	3,185	17,084	28.8
Total	59,390	100.0	38,345	9,020	12,029	59,394	100.0

[a] Export includes any activity that brings dollars to the Klamath economy. The dependency index is the percentage of jobs that are dependent on payments to households from outside the lower Klamath Basin

Source: Weber and Sorte 2002.

jobs in the wood-products manufacturing sector, but 7018 jobs in the region were dependent on wood products exports.

Of these, 3089 jobs were directly dependent on the export of wood products from the county where they were produced; these jobs were related to direct purchases from wood-products firms by households, firms, and governments outside the region. In addition, 2126 jobs were indirectly dependent on wood-products exports; these jobs were created when wood-products firms purchased inputs (such as logs) from firms in the county and when the suppliers purchased from other businesses in the county. Yet another 1803 jobs were induced by exports of wood products; these jobs were in retail trade, real estate, and health care and were created when households respent income earned in all of jobs generated directly and indirectly by export of wood products. The spending and respending of money brought into the region by export of wood products generated a total of 6922 jobs.

Table 2-4 indicates the dependence of the basin's regional employment on two natural-resources sectors. Agriculture (agriculture and related plus food-products manufacturing) supports 13.7% of the region's jobs, and wood products (forestry and logging plus wood products manufacturing) supports 12.5%.

Table 2-4 also identifies the dependence of the regional economy on two sectors that often are the focus of local economic development efforts. Although the tourism sector (accommodation and food services; arts, entertainment, and recreation) is responsible for 10% of the total jobs in the region, it contributes only 3.4% of the export employment base. Retail trade, the sector with the largest employment share (11.1%), provides only 1% of the export employment base.

Table 2-4 also shows that regional employment is more dependent on income of households outside the region than on any single sector. Household income from government transfer payments (for example, social security), dividends, commuters' income, rental payments, and other sources of income originating outside the region supported 17,084 jobs (28.8%) in 1998.

The dependence of the basin's economy on federal and state government and educational institutions also is evident in Table 2-4. Almost one-fifth of the jobs in the region depend on federal and state funding for such services as education and other public services. Public administration, which supports 10.1% of jobs, includes federal and state payments to local governments (for example, federal payments in lieu of taxes, federal forest payments, and state-shared cigarette and highway revenues) and to government personnel (in USFS, USDA, and USFWS, for example). State and federal funding of educational services (such as K-12 schools, the community college in California, and the Oregon Institute of Technology) and tuition payments by nonresidents support 9.8% of the region's jobs.

There were 2239 farms in the upper Klamath basin in 1997 (Table 2-5). A farm is defined as "any place from which $1,000 or more of agricultural products were produced or sold, or normally would have been sold, during the census year" (USDA 1999, p. VII: http://www.nass.usda.gov/census/census97/volume1/us-51/us1into.pdf). Farms thus include many places that do not depend significantly on farm income. Indeed, as shown in Table 2-5, 29% of farm operators work more than 200 days per year off the farm, and only 60% consider farming their primary occupation. Just over half the farms (57%) have more than $10,000 in annual sales.

Table 2-5. Characteristics of Upper Klamath Basin Farms and Farm Operators, 1997

Farm Characteristic	Klamath, OR	Siskiyou, CA	Modoc, CA	Upper Basin Total
Number of farms	1,066	733	440	2,239
Land in farms (acres)	713,534	628,745	662,927	2,005,206
Average size of farm (acres)	669	858	1,507	896
Farms with sales >$10,000 (%)	54	55	69	57
Farms with irrigation (farms)	851	556	337	1,744
Irrigated land (acres)	243,205	139,534	159,219	541,958
Market value of agricultural products sold ($000)	100,622	74,244	63,797	238,663
Net cash return from agricultural sales for the farm unit ($000)	20,104	16,389	11,249	47,742
Average net cash return per farm ($)	18,859	22,359	25,556	21,323
Government payments received ($000)	817	1,420	666	2,903
Farms receiving payments (%)	16	21	25	19
Average government payments per farm receiving payments ($)	4,750	9,467	6,055	6,720
Farms with hired labor (farms)	380	259	206	845
Farms with hired labor (%)	37	35	47	38
Number of hired farm workers (workers)	1,779	2,795	1,664	6,238
Workers working 150+ days (%)	37	17	21	24
Hired farm labor payroll ($000)	9,745	11,309	6,169	27,223
Average annual pay per hired farm worker ($)	5,478	4,046	3,707	4,364
Sole-proprietor farms (%)	83	82	82	82
Farm operators living on farm operated (%)	82	78	72	78
Operators with farming as primary occupation (%)	58	61	65	60
Farm operators working more than 200 days off-farm (%)	33	27	23	29

Sources: USDA 1999, Weber and Sorte 2002.

Farms averaged 896 acres; 78% had some irrigation, and 27% of the region's farmland is irrigated. Most farms (82%) are sole proprietorships, and 78% are operated by the person living on the farm. About one-third of the farms (38%) hire farm workers. The average annual pay per hired farm worker was $4364. About one-fourth (24%) of the 6238 farm workers worked 150 days or more in 1997.

Net cash return per farm from agricultural sales in the upper Klamath basin averaged $21,323 in 1997. Net cash return equals the value of agricultural products sold minus operating expenses (not including depreciation). Almost one-fifth of the farms (19%) received government payments in 1997, which averaged $6720.

Table 2-6 reports the value of agricultural production by commodity for each upper Klamath basin county and for the region. The regional value of total agricultural production in 1998 was estimated to be $283 million. Cattle, hay, and pasture accounted for 58% of the value of production, but potato production was also important (15%).

Farm income in the upper Klamath basin, as elsewhere, varies considerably from year to year and from county to county. BEA provides county-level estimates of realized net income from farming, farm proprietors' income, and farm-labor income. Realized net income is equal to total cash receipts from marketing plus other income (including government payments, such farm-related income as custom work and rent, and imputed rent for farm dwellings) minus total production expenses (including depreciation). In 1997, realized net income in the upper Klamath basin was $30 million, and incomes were positive in all counties. In 1998 (not shown in Table 2-5), realized net farm income in the upper Klamath basin was less than in 1997 (about $1.2 million), and in Klamath County it was negative (-$7 million). BEA estimates farm labor income at $24 million for 1997 and $26 million for 1998 (the 1997 Census of Agriculture estimates hired farm-worker payroll at $27 million).

Farm employment is not as variable as farm income. BEA estimates that there were 2601 farm proprietors in 1997 and 2702 in 1998. The Census of Agriculture reports only 2239 farm operators in 1997 (Table 2-5, USDA 1999). BEA estimates full- and part-time farm wage and salary employment at 1812 in 1997 and 1491 in 1998. The Census of Agriculture reports more than 4 times as many hired farm workers (6238) in the upper Klamath basin in 1997 (Table 2-5, USDA 1999). The Oregon Employment Department estimate of total agricultural (worker) employment in Klamath County in 1997 was 1490, twice the BEA estimate of 784, suggesting that BEA substantially undercounts farm workers.

The Klamath Reclamation Project provides water to 63% of the 2239 farms and to 80% of the irrigated farms in the upper Klamath basin (Table 2-7). The Klamath Project contains 36% of the region's irrigated acreage. Farms served by the Klamath Project produce almost half (45%) the value of agricultural sales in the region.

Lower Basin

Except for regulation of releases at Iron Gate Dam, USBR's Klamath Project is disconnected from the lower basin, but the economic implications of measures that may be necessary to facilitate the recovery of coho and benefit other fishes along the Klamath main stem may be considerable for the lower basin.

Table 2-6. Value of Agricultural Production (Thousands of Dollars) in Upper Klamath Basin, 1998, by County

Commodity	Klamath, OR	Siskiyou, CA	Modoc, CA	Upper Basin Total	Share of Total Value of Production, %
Alfalfa hay	30,726	25,203	12,825	68,754	24.3
Cattle	32,850	23,635	9,000	65,485	23.2
Potatoes	14,217	19,323	7,866	41,406	14.6
Pasture and range	n/a	13,005	7,560	20,565	7.3
Other hay	4,856	3,713	3,588	12,157	4.3
Barley	5,225	3,280	2,187	10,692	3.8
Onions	n/a	2,862	2,464	5,326	1.9
Wheat	1,660	2,805	859	5,324	1.9
Dairy	13,112	2,442	n/a	15,554	5.5
Horseradish	n/a	n/a	896	896	0.3
Sugarbeets	3,832	n/a	3,284	7,116	2.5
Nursery products	n/a	17,271	n/a	17,271	6.1
Other	1,000	5,319	5,973	12,292	4.3
Total	107,478	118,858	56,502	282,838	100

Abbreviations: n/a, not applicable.
Source: Oregon State University Extension Service, California Agricultural Statistics Service.

As explained in this chapter, irrigation-based economies are important in the Shasta and Scott rivers and in the Trinity River, which has been studied specifically with reference to water transfers that generate economic benefits outside the watershed. Changes in irrigation practices and facilities may be necessary for the benefit of the coho and other species, and any such changes in the lower basin would need to be carried out with the cooperation of private water providers and private landholders. As will be shown in Chapters 7 and 8, present timber management and mining practices may also be inconsistent with the welfare of the coho salmon and may require modification, which could affect both public entities and private parties. Commercial fishing is involved economically in the restrictions on take, which are a disadvantage in the short term, and in efforts at restoration, which potentially provide long-term benefits.

The lower Klamath basin includes parts of three counties in northwestern California: Del Norte, Humboldt, and Trinity. The Klamath River flows from the upper basin in Klamath County, Oregon, into Modoc and Siskiyou counties, California, and then to the lower basin in northern Humboldt County. It continues through southern Del Norte County before reaching the Pacific Ocean near Requa, California. Although the Klamath River itself does not flow through Trinity County, the county is drained mostly by the Trinity River, which is the largest tributary of the Klamath River. The basin does not include Crescent City, the county seat in Del Norte County, or the region's most populous area, Humboldt Bay (including Eureka and Arcata) in Humboldt County. Because demographic and economic statistics are gathered for government jurisdictions, the analysis that follows includes all three relevant counties. Humboldt County dominates the region demographically and economically; it has three-fourths of the region's population and over three-fourths of its full- and part-time jobs. The economy of the lower

Table 2-7. Farms in the Klamath Reclamation Project and in the Upper Klamath Basin

Irrigated Farms, 1997		Irrigated Acres, 1997 (1000s)		Value of Sales, 1997 ($000)	
Basin	Project	Basin	Project	Basin	Project
1,744	1,400	542	195	$238,663	$108,539

Sources: USDA 1999; and Tables 1 and 2 from Burke 2002.

Klamath basin, which is home to about 167,000 people, in 1998 produced $5.9 billion worth of output, added $3.3 billion in value to purchased inputs, and had more than 84,000 jobs.

Much of the information given below is derived from a report by Sorte and Wyse (in press) and like information on the upper Klamath basin, is based on longitudinal data from BEA; profiles of farm numbers, type, and production from the 1997 Census of Agriculture (USDA 1999) and California County agricultural commissioners' reports; and information from a proprietary input-output economic IMPLAN model constructed by the Minnesota IMPLAN Group, Inc. The IMPLAN model was edited by using agricultural-production data from the California Agricultural Statistics Service, employment data from BEA's Regional Economic Information Service, and fisheries data from Hans Radtke and Shannon Davis of The Research Group, Corvallis, Oregon. Because a number of data sources were used, there is some variation in the categories used to aggregate the industrial sectors and to estimate the number of jobs in each sector.

From 1969 to 1999, full- and part-time employment in the lower Klamath basin increased by 171% from 49,000 to 84,000 jobs. Over the same period, employment in California increased by 211%, and U.S. employment by 180%. As in the upper basin, the composition of the regional economy changed substantially over this time. A summary of the changes is provided in Table 2-8. In the lower basin, the sectors that grew most were construction and services. The share of jobs in construction grew from 2.9% to 5.4% of the total; jobs in services grew from 16.6% to 29.9%. Modest growth occurred in agricultural services, forestry, fishing, and other; retail trade; and finance, insurance, and real estate. Employment declined in the mining, manufacturing, and military sectors. Lower than average growth occurred in the farming, transportation and public utilities, wholesale trade, and federal civilian sectors.

Table 2-9 gives estimates of some basic economic indicators and their distribution among sectors for 1998. This table, which is based on data from Minnesota Implan Group's Input-Output IMPLAN Model, varies slightly from Table 2-8, which is based solely on Bureau of Economic Analysis data. The sectors with the largest shares of output in 1998 were combined wood products including forestry and logging and manufacturing – wood products, etc. (19.8%), construction (8.4%), retail trade (6.8%), and combined agriculture including agriculture, fishing and related and manufacturing – food, etc. (6.5%). The four sectors with the largest shares of value added were wood products (12.4%), retail trade (10.4%), educational services (9.8%), and health care and social assistance (9.4%).

Retail trade (12.8%), educational services (12.2%), and health care and social assistance (11.8%) had the greatest shares of jobs in the economy.

As noted for the upper-basin economy, output, value added, and employment measures indicate the magnitude and distribution of economic activity among sectors in a region. The

[illegible] Structural Change in the Lower Klamath Basin Economy, 1969-1999

Sector	Employment 1969	%	Employment 1999	%	Employment Change 1969-1999	%
Total full and part-time employment	49,107	100.0	84,192	100.0	35,085	71.4
Wage and salary employment	40,867	83.2	64,298	76.4	23,431	57.3
Proprietors' employment	8,240	16.8	19,894	23.6	11,654	141.4
Farm proprietors' employment	917	1.9	1,166	1.4	249	27.2
Nonfarm proprietors' employment	7,323	14.9	18,728	22.2	11,405	155.7
Farm employment	1,517	3.1	2,320	2.8	803	52.9
Nonfarm employment	47,590	96.9	81,872	97.2	34,282	72.0
Private employment	37,780	76.9	66,238	78.7	28,458	75.3
Agricultural services, forestry, fishing, & other	1,176	2.4	2,859	3.4	1,683	143.1
Mining	105	0.2	50	0.1	-55	-52.4
Construction	1,429	2.9	4,531	5.4	3,102	217.1
Manufacturing	12,747	26.0	7,986	9.5	-4,761	-37.3
Transportation and public utilities	2,936	6.0	3,077	3.7	141	4.8
Wholesale trade	1,219	2.5	1,968	2.3	749	61.4
Retail trade	7,667	15.6	15,498	18.4	7,831	102.1
Finance, insurance, and real estate	2,332	4.7	5,098	6.1	2,766	118.6
Services	8,169	16.6	25,171	29.9	17,002	208.1
Government and government enterprises	9,810	20.0	15,634	18.6	5,824	59.4
Federal civilian	1,007	2.1	1,235	1.5	228	22.6
Military	1,495	3.0	473	0.6	-1,022	-68.4
State and local	7,308	14.9	13,926	16.5	6,618	90.6

Table 2-9. Output, Value Added, and Employment in Lower Klamath Basin, 1998

Industry	Output		Value Added		Employment	
	$ Million	Share (%)	$ Million	Share (%)	Jobs	Share (%)
Agriculture, fishing & related	186.034	3.2	120.316	3.6	4,055	4.9
Mining	9.013	0.2	4.583	0.1	56	0.1
Construction	496.378	8.4	179.237	5.4	5,017	6.0
Manufacturing—food, beverages, textiles & related	192.714	3.3	31.680	1.0	934	1.1
Forestry and logging	180.966	3.1	75.554	2.3	1,286	1.5
Manufacturing—wood products, paper, furniture & related	983.314	16.7	335.536	10.1	5,175	6.2
Manufacturing—high technology and related	12.676	0.2	4.280	0.1	67	0.1
Manufacturing—other	129.025	2.2	43.022	1.3	936	1.1
Transportation and warehousing	258.081	4.4	111.594	3.4	2,730	3.3
Utilities	300.116	5.1	132.448	4.0	853	1.0
Wholesale trade	181.920	3.1	124.520	3.8	2,196	2.6
Retail trade	399.214	6.8	346.514	10.4	10,623	12.8
Accommodation and food services	208.678	3.5	115.597	3.5	6,486	7.8
Finance and insurance	264.670	4.5	194.334	5.9	2,887	3.5
Real estate, rental, and leasing	389.385	6.6	283.234	8.5	1,444	1.7
Other services	252.268	4.3	139.735	4.2	6,997	8.4
Information	133.216	2.3	64.861	2.0	1,179	1.4
Administrative and support services, and so on	44.278	0.8	26.773	0.8	1,225	1.5
Arts, entertainment, and recreation	31.921	0.5	19.466	0.6	1,189	1.4
Health care and social assistance	522.509	8.9	312.115	9.4	9,799	11.8
Professional, scientific, and technical services	126.789	2.2	87.384	2.6	2,812	3.4
Educational services	354.574	6.0	326.439	9.8	10,162	12.2
Public administration	238.337	4.0	238.337	7.2	5,113	6.1
Inventory valuation adjustment	0.301	0.0	0.301	0.0	0	0.0
Total	5,896.375	100.0	3,317.859	100.0	83,220	100.0

magnitude of economic activity in a sector, however, does not necessarily reflect the extent to which the sector sustains economic activity in the region.

Table 2-10 summarizes the contribution of each sector to total regional employment, and is based on an analysis that used the Lower Klamath Basin Input-Output Model, which was developed for this report. The jobs under the sectoral employment columns are within the sector, whereas the jobs in the export-dependent columns are from all sectors that depend on the exports from a sector. For example, there were 5017 jobs in the construction sector but 6941 jobs in the region depended on construction exports (for example, building homes for retirees from outside the region or construction roads for federal or state governments). Of those, 3886 jobs depended directly on the exports of construction services from the region; these jobs were related to direct purchases from construction firms from household, firms, and governments outside the region. In addition, 1687 jobs depended indirectly on construction exports; these jobs were created when construction firms purchased inputs (for example, building materials) from firms within the region and when the suppliers purchased from other businesses in the region.)

Another 1368 jobs were induced by exports of wood products; these jobs were in sectors like retail trade, real estate, and health care that were created when households respent income earned in all the jobs generated directly and indirectly by exports of wood products. The spending and respending of money brought into the region by exports of construction generated a total of 6941 jobs.

Table 2-10 shows that the lower-basin economy depends on the natural-resources sectors, although not to the same extent as that of the upper basin. The combined agricultural sectors support 6.3% of the region's jobs, and the combined wood products sectors support 13.9%. Together, these two natural-resources sectors make up about 20.2% of the lower-basin economy. In the upper basin, the agricultural sector supports 14% of the region's jobs, and wood products supports 12.5%, for a total of about 27% of the economy. Table 2-10 also identifies the dependence of the lower-basin regional economy on four other sectors that often are the focus of local economic development efforts, particularly in rural economies oriented to natural resources. Specifically, these are the sectors that include substantial activity related to tourism associated with visitors from outside the region, such as retail trade, accommodation and food services, other services, and arts, entertainment, and recreation, which together contribute 12.5% of the export employment base (slightly more than in the upper basin). Still, these tourism sectors remain primarily service sectors. For example, the retail-trade sector's share of sectoral employment is 12.8%, and it provides just 3.8% of the export employment base.

The lower basin's employment, like the upper basin's, depends heavily on income to households. Household income from government transfer payments (such as social security), dividends, commuters' income, rental payments, and other sources of income originating outside the basin is the most important part of the export base. In 1998, 17,191 jobs, or 20.7%, depended on those payments.

The dependence of the basin's economy on federal and state government and educational institutions is also evident in Table 2-10. Almost one-fourth of the jobs in the region depend on federal and state funding for services, such as education and other public services. Public administration supports 8.0% of all jobs in the basin; this sector includes federal and state payments to local governments (such as federal payments in lieu of taxes, federal forest

Table 2-10. Export Based Employment, Lower Klamath Basin, 1998

Sector	Sectoral Employment		Export Dependent Employment				
	No. Jobs	%	Direct	Indirect	Induced	Total	Dependency Index
Agriculture, fishing, and related	4,055	4.9	2,815	461	662	3,937	4.7
Mining	56	0.1	55	14	25	95	0.01
Construction	5,017	6.0	3,886	1,687	1,368	6,941	8.3
Manufacturing—food, beverages, textiles & related	934	1.1	617	491	210	1,319	1.6
Forestry and logging	1,286	1.5	641	549	291	1,482	1.8
Manufacturing—wood products, paper, furniture, and related	5,175	6.2	4,525	3,126	2,393	10,044	12.1
Manufacturing—high technology and related	67	0.1	31	18	15	64	0.1
Manufacturing—other	936	1.1	913	403	393	1,708	2.1
Transportation and warehousing	2,730	3.3	849	425	418	1,691	2.0
Utilities	853	1.0	262	349	274	885	1.1
Wholesale trade	2,196	2.6	367	72	110	549	0.7
Retail trade	10,623	12.8	2,570	95	457	3,123	3.8
Accommodation and food services	6,486	7.8	1,676	170	202	2,048	2.5
Finance and insurance	2,887	3.5	705	96	188	988	1.2
Real estate, rental, and leasing	1,444	1.7	227	90	61	377	0.5
Other services	6,997	8.4	3,819	402	574	4,794	5.8
Information	1,179	1.4	184	78	56	317	0.4
Administrative and support services, and so on	1,225	1.5	229	90	61	380	0.5
Arts, entertainment, and recreation	1,189	1.4	255	20	26	301	0.4
Health care and social assistance	9,799	11.8	3,500	565	841	4,906	5.9
Professional, scientific, and technical services	2,812	3.4	809	76	192	1,077	1.3
Educational services	10,162	12.2	9,645	112	2,605	12,362	14.9
Public administration	5,113	6.1	5,113	43	1,487	6,643	8.0
Inventory valuation adjustment	0	0.0	0	0	0	0	0.0
Households (for example, social security)[a]	0	0.0	12,268	2,032	2,891	17,191	20.7
Total	83,220	100.0	55,960	11,461	15,799	83,220	100.0

[a]Households do not represent an industry sector with employees so have zero sectoral employment. They do spend a portion of their transfer payments on goods and services (e.g., food and health care) within the region, so they have an induced effect on the economy.

payments, and state-shared cigarette and highway revenues) and to government personnel (USFS, USDA, and USFWS, for example). State and federal funding for educational services plus tuition payments by nonresidents support 14.9% of the region's jobs.

Two important industries based on natural resources, agricultural crop and livestock production and fisheries, are aggregated and summarized in the tables as the agriculture, fishing, and related sector. Because they are both so strongly affected by water resources in the Klamath basin, some additional review of these industries follows.

Using the same definition of a farm as in the upper basin, there were 974 farms in the lower Klamath basin in 1997, that is about 40% of the number of farms in the upper basin (Table 2-11). As noted in the discussion regarding the upper basin, farms include many places that do not depend on their farm operations as their major source of income. Indeed, as shown in Table 2-11, 35% of farm operators work more than 200 days/yr off the farm, and only 51% consider farming their primary occupation. Fewer than half the farms (45%) have more than $10,000 in annual sales. Farms averaged 653 acres; 39.5% had some irrigation and 3.7% of the region's farmland is irrigated. Over half the farms (61%) are sole proprietorships, and 72% are operated by the person living on the farm. About one-third of the farms (35%) hire farm workers. The average annual pay per hired farm worker was $6754. Thus, the number of farm workers in the lower basin is about one-third the number in the upper basin, but the average pay per worker is greater in the lower basin. About half (44%) the 2183 farm workers worked 150 or more days in 1997.

Net cash returns per farm from agricultural sales in the lower Klamath basin averaged $23,016 and were similar to those of the upper basin ($21,323) in 1997. Net cash returns equals the value of agricultural products sold minus operating expenses (not including depreciation). Very few farms (3.1%) received government payments in 1997, which averaged $2000.

Table 2-12 reports the value of agricultural production by commodity for each of the counties in the lower Klamath basin and for the region. The regional value of total agricultural production in 1998 was estimated to be $114 million, compared with $283 million in the upper basin. Dairy and nursery products are the principal agricultural products of the region, together accounting for 75.6% of the value of agricultural-commodity production. Cattle and livestock products are also important; they account for 13.7% of the value of agricultural commodity production.

Fishing is an important part of the culture of the lower-basin culture and the economy. Table 2-13 provides information on catch and value for the fishing industry in 1997-2001. The catch information reflects only ocean-related commercial fishing, not fishing in rivers. The lower Klamath basin input-output model explicitly considers ocean fishing in the agriculture, fishing, and related sectors because the catch is sold directly for processing or consumption. River fishing is included only indirectly in the model; that economic activity and other activities related to fish in the Klamath River main stem are reflected primarily in the tourism sectors. Thus, the actual effects of fish migration through the Klamath basin are difficult to estimate accurately. As Table 2-13 indicates, commercial fishing had a value of $12.4 million in 2001, which was less than in prior years and continues to steadily decline.

In relative terms, commercial fishing accounts for about 10% of the value of agriculture in the lower basin. The most valuable components of the catch are groundfish ($5.5 million in

Table 2-11. Characteristics of Lower Klamath Basin Farms and Farm Operators, 1997

Farm Characteristic	Del Norte County	Humboldt County	Trinity County	Lower Basin Total
Number of farms	66	792	116	974
Land in farms (acres)	13,303	584,538	118,252	716,093
Average size of farm (acres)	202	738	1019	653
Farms with sales >$10,000 (%)	41	49	22	45
Farms with irrigation (farms)	24	301	70	395
Irrigated land (acres)	6,323	17,630	2,212	26,165
Market value of agricultural products sold ($000)	20,797	75,475	1,797	98,069
Net cash return from agricultural sales for the farm unit ($000)	5,229	17,700	-489	22,440
Average net cash return per farm ($)	79,234	22,320	-4,216	23,016
Government payments received ($000)	0	54	6[a]	60
Farms receiving payments (%)	0	3.4	2.6	3.1
Average government payments per farm receiving payments ($)	0	2,000	2,000[a]	2,000
Farms with hired labor (farms)	32	279	32	343
Farms with hired labor (%)	48	35	28	35
Number of hired farm workers (workers)	652	1,345	186	2,183
Workers working 150+ days (%)	47	47	18	44
Hired farm labor payroll ($000)	5,579	8,690	476	14,745
Average annual pay per hired farm worker ($)	8,557	6,461	2,559	6,754
Sole proprietor farms (%)	64	59	78	61
Farm operators living on farm operated (%)	70	73	80	72
Operators with farming as primary occupation (%)	50	53	43	51
Farm operators working more than 200 days off farm (%)	33	35	38	35

[a]Information not disclosed by the Census of Agriculture because few farms (three) received assistance. Average payment of $2000 was estimated because in 1992 the average was $2,236 for Trinity County and in 1997 the average was $2000 for Humboldt County.
Source: USDA 1999.

Table 2-12. Value of Agricultural Production in the Lower Klamath Basin, 1998

Commodity	Value of Agricultural Production, $000 Del Norte $	Humboldt $	Trinity $	Lower Basin Total $	Share of Total Value of Production %
Dairy	10,578	39,028	0	49,606	43.5
Nursery products	13,322	23,277	37	36,636	32.1
Cattle and livestock products	3,495	11,074	1,088	15,657	13.7
Hay and pasture	1,351	8,179	463	9,993	8.8
Vegetables	75	676	32	783	0.7
Sheep, lambs, and wool	38	116	8	162	0.1
Fruit and nuts	435	91	105	631	0.6
Other	472	20	49	541	0.5
Total	29,766	82,461	1,782	114,009	100.0

Source: California Agricultural Statistics Service.

2001) and crab and lobster ($4.1 million in 2001). Salmon (Chinook) landings were valued at about $0.2 million in 2001.

The economic effects of eliminating or reducing any of the ocean fisheries in the lower-basin economy can be calculated with the same procedure used earlier to determine the export dependency indexes. Using the detailed multi-sector version of the Lower Klamath Basin Input-Output Model, which is based on the 1998 IMPLAN model, to be consistent with the upper basin analysis, the effect of removing all the salmon catch in 2001 ($107,887), assuming that the catch is exported from the region, is a total loss to the regional economy of $164,507. This effect, though relatively small in comparison to the commercial fishing industry or the total regional economy, did extend across 193 of the 204 sectors in the regional economy. Commercial fishing has a multiplier of approximately 1.5 on both employment and output in the region. Thus, for every dollar or job directly involved in commercial fishing there is approximately another fifty cents or half a job lost as suppliers or businesses that sell to those working in fishing, or for the suppliers or businesses experiencing reduced sales. The current economic effects of the commercial salmon catch may significantly understate the potential contribution of the salmon fishing to the economy of the lower Klamath basin. Salmon landings at the ports of Eureka and Crescent City have declined by more than 95% since the 1970s. If the average 1976-1980 landings from the two ports of 2,547,000 round lb could be reached, and they were sold at 2001 prices of $1.47 per lb, the combined output from the salmon fishery would be $3,744,090. The estimated value-added component of that level of output in 2001 dollars would be $2,476,908. Returning to that level of output would require an estimated 67 direct jobs in the commercial fishing sector. The multiplied effect of these jobs on commercial fishing to businesses that supply the fisheries sector and from household expenditures in service sector businesses could be an additional 30 jobs, for a total of 97 jobs. These estimates of the economic effects of increased salmon harvest assume the catch is exported outside the region and that the effects are not reduced by changes that might be necessary to achieve the increases (e.g., shifting water from irrigated agriculture to increase stream flows).

In summary, the economics of the upper and lower basins display characteristics common to many rural economies, including heavy reliance on natural resources sectors, such as

Table 2-13. Fisheries Characteristics of Ports of Eureka (Humboldt County) and Crescent City (Del Norte County)

	Round Pounds					Value (Nominal), $				
Species Group	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001
Groundfish	16,246,794	13,888,084	12,036,198	10,116,024	8,708,018	9,309,576	6,615,305	6,308,414	6,631,668	5,461,928
Pacific whiting	13,958,624	12,614,230	2,881,997	10,988,772	5,081,398	581,399	391,780	115,275	764,851	170,967
Salmon (troll chinook)	16,675	26,450	34,500	26,450	73,600	21,298	41,427	61,577	42,795	107,887
Crab and lobster	6,454,585	7,425,668	7,122,922	4,764,952	1,719,814	11,132,662	12,193,371	13,210,063	9,403,268	4,073,747
Shrimp	12,441,711	1,460,207	3,658,543	2,170,063	3,447,869	5,020,462	951,542	1,982,483	1,172,213	1,236,641
Coastal pelagic	176,167	161,285	46,246	14,168	148,548	93,398	39,260	11,365	7,879	52,975
Highly migratory	2,222,487	727,022	647,952	823,779	1,414,603	1,870,065	764,542	630,488	841,564	1,155,138
Halibut	9,007	477	891	289	8	17,866	790	1,669	723	16
Sea urchins	63,624	2,357	36,532	3,735	22,595	35,352	825	26,438	3,224	12,279
Other	1,822,974	564,703	597,413	841,699	388,929	509,044	227,912	217,430	262,536	138,378
	53,412,648	36,370,483	27,063,194	29,793,910	21,005,382	28,591,122	21,226,754	22,565,202	19,130,721	12,409,956

Source: Hans Radtke and Shannon Davis, unpublished.

agriculture and wood products. Together, the entire basin showed economic activity valued in 2002 at $10.5 billion. Of that, about 26% (or $2.7 billion) was derived from sectors based on natural resources. Reliance on such sectors is slowly declining across both the upper and lower basins.

OVERVIEW

The Klamath basin is exceptionally diverse geomorphically because it has been strongly influenced by both crustal movement and volcanism. Geomorphic diversity in the basin has produced a wide variety of aquatic habitats, including extensive wetlands, large shallow lakes, swiftly flowing mainstem waters, and various tributary conditions. The watershed is not densely populated but shows strong anthropogenic influences of several kinds. Management of water for irrigation, which has been in progress for more than a century, has altered the basic environmental conditions for aquatic life, including the hydrographic features of flowing waters, the distribution and extent of wetlands, and the extent and physical characteristics of the lakes that were found originally in the basin. Of the total economic activity in the Klamath basin ($10.5 billion), about 26% is derived from natural resources, including mostly agriculture, wood products, and ocean fishing. Irrigation and agricultural practices have blocked or diverted fish from migration pathways, caused adverse warming of waters, and augmented nutrient transport from land to water. Commercial fishing also has left a mark through depleted stocks of some species and, although now controlled, may have had legacy effects that are difficult to reverse. Timber harvest and mining along tributaries have caused, and in some cases continue to cause, severe physical impairment of aquatic habitats. Although aquatic habitats now are regarded as valuable for the maintenance of native species, remediation of damage to habitat presents great difficulties because of the extent and diversity of changes that have occurred in the basin over the last century.